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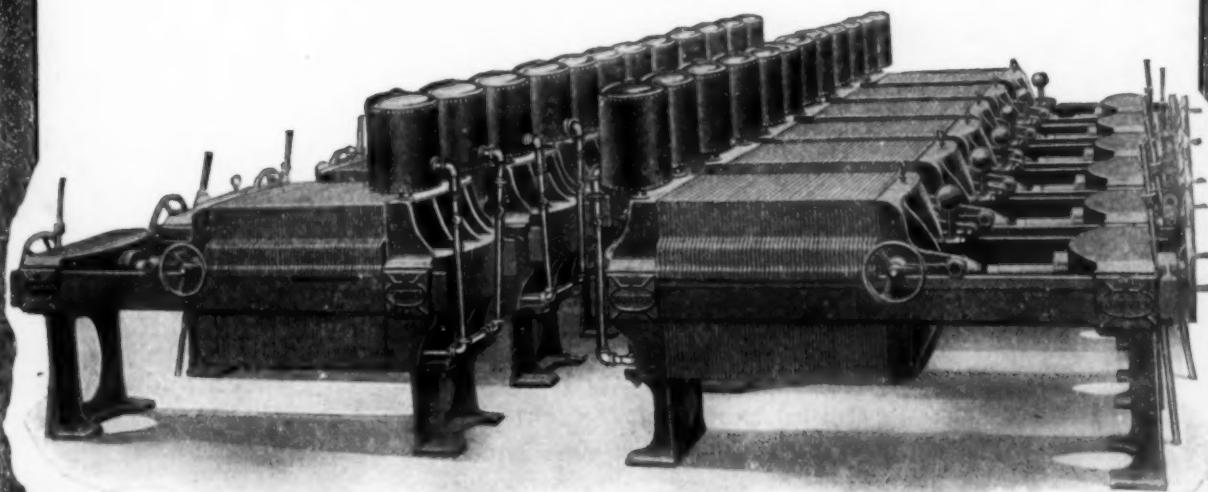
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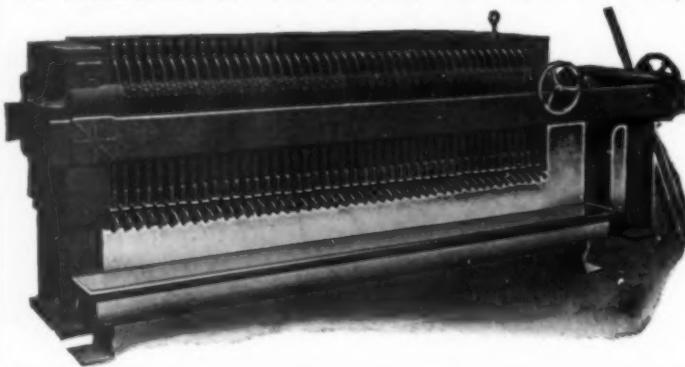
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Central Research Organizations

Research is the order of the day in metallurgy. The time was when companies moved along in an even tenor, more satisfied than dissatisfied with their processes, showing little disposition to look for improvements or new ideas as long as they met with financial success. They limited their operations to the treatment of ores readily amenable to comparatively simple processes, and took the cream of mineral production. The number of technically trained men was small, and operations were conducted more by rule-of-thumb. Such were the conditions that inevitably surrounded the inception of the metallurgical industry in the West.

Development in the arts, sciences and technology has been accompanied by a vast increase in the number of trained workers who have the spirit of investigation demanded by the intricate problems that have come hand in hand with the change in economic conditions. To-day no concern of importance rests on its laurels. Research departments are maintained in various degrees of magnitude. Appropriations from earnings are regularly made for the support of investigation. Methods of operation change so rapidly that one is kept busy if he would be in touch with developments from month to month.

All of this represents a state of healthy discontent, and contributes greatly to progress. But the question arises: Is metallurgical research being conducted to the greatest economic advantage? Is progress as rapid under a system in which each company maintains its corps of workers, as it would be if groups of companies engaged in similar pursuits supported a central research organization? Instances could be cited which apparently warrant an answer in the negative, though there is no thought of suggesting that the idea is of universal application.

Consider, for example, the research work of the established copper companies. A half dozen could be promptly named that are investigating hydrometallurgical and other processes of common interest. Not forgetting that each problem is in some measure peculiar to itself, we presume there must be some fundamental features common to all, which, once solved, would be of general benefit. And yet each investigator is working individually on the same problem. Not only is a great deal of work needlessly duplicated, but time and money are consumed without profit. Perhaps several men carry on investigations to the same point and then abandon them. Later, another investigator, not fully informed, repeats all the work and ends at the same point instead of taking advantage of previous work and starting where others stopped.

Of course, the usual objection to centrally organized

research is found in individual ambition and professional jealousy. Each wants credit for his work, and fears to lose his identity in a larger scheme. But there might be just as much pride in belonging to a fine organization as in working alone, and the economic results ought to be greater. Even under present conditions there is willingness to "swap ideas," and representatives of the large companies are constantly visiting back and forth, so that some degree of benefit accrues from the interchange of knowledge. But even so, there is much duplication of work and unproductive experimenting for which the industry pays several times instead of once. Separate research departments have proved valuable. May not central organizations be the next economic step?

Aesop at Niagara Falls

Our friend the *Mining and Scientific Press* of San Francisco, writes as follows:

"Much as we admire our brilliant contemporary, *Metallurgical and Chemical Engineering*, we cannot accompany it on its forays into the realms of natural history. Recently it sought to illustrate the present situation at Niagara Falls by means of a fable in which a beaver and an eagle enter into an agreement to divide the fish they catch, an arrangement which worked admirably until a tiger appeared and demanded a share of the spoil. Possibly the metamorphoses effected by the metropolitan fur dealers, who without difficulty transmute a raccoon into a Hudson seal, have so bewildered the New York editor that he confuses a beaver with an otter and an eagle with an osprey, but where does the tiger come in? Fortunately Mr. Theodore Roosevelt is still in South America and the life of the nature-faking chemical engineer is therefore not in immediate danger, but we advise him to accept an engagement which will take him to the Lena goldfields, or some equally inaccessible place, at the earliest possible moment."

We have heard of a fox with an appetite for grapes; but East is East and West is West, and fish stories are not understood by some people.

The Steel Corporation's Report

The United States Steel Corporation began business April 1, 1901, so that the report for 1913, just issued, covers its twelfth full calendar year. The 1913 earnings, \$137,181,345, make the best showing for a year with but three exceptions, 1906, 1907 and 1910. The tonnage of steel products measured in the form in which sold, 12,374,838 tons, stands second to that of but one year, 1912, and is only 1 per cent below the total for that year. The earnings per ton in 1913, \$11.09, are naturally less than in any of the three years in which total earnings were larger. They are indeed smaller than those of eight of the twelve years, viz., 1902, 1903, 1905, 1906, 1907, 1908, 1909, and 1910, and they exceed those of 1911 by only 8 cents.

Thus the Steel Corporation has in its twelve years of life somewhat increased its total earnings, while it has greatly increased its tonnage, and its earnings per ton have very materially decreased. In its last three years its total earnings have been materially greater than in its first three years.

There was a remarkable increase in the Steel Corporation's labor cost in 1913. The comparative figures are as follows:

	1912	1913
Average number of employees	221,025	228,906
Total salaries and wages....	\$189,351,602	\$207,206,176
Average per employee per day:		
Excluding general administrative and selling force	\$2.68	\$2.85
Including general administrative and selling force	2.75	2.92

The total output decreased from 1912 to 1913 by about 1 per cent. Furthermore, the output of sheets and tinplates decreased from 12.8 per cent of the total to 10.3 per cent of the total. Of the important branches, this is the one which employs the largest number of men per ton of output, and of the number employed a large proportion are highly paid tonnage men. It is, therefore, remarkable that the total number of employees increased by 3.57 per cent. The larger increase in total wages and salaries paid, 9.43 per cent, reflects the general wage advance made effective Feb. 1, 1913, which affected about 75 per cent of all employees, giving them advances ranging from 12½ per cent in the case of the lower paid men down to smaller percentages for higher paid men.

Inasmuch as the average degree of finish of the Corporation's output has increased, trustworthy comparisons cannot be made, but it is interesting to note that its apparent wage and salary cost, per ton of output in the form in which sold, was \$14.94 in 1902 and \$16.76 in 1913, an increase of 12 per cent. Meanwhile the average pay per man increased 26 per cent. Having regard to the higher degree of finish attained in the average ton of product, the manual effort per ton has probably decreased, but only slightly. The remuneration in proportion to effort has probably increased considerably. It is quite possible that the increase in wages received has not fully equaled the increase in the cost of living, but there is the very important fact that the average selling prices of steel have greatly decreased since 1902. Realized prices upon steel were very much lower in 1913 than in 1902. The margin per ton of output has decreased, but interest and dividend payments have been maintained through the production of a larger tonnage.

Engineering Education

The recent announcement that Harvard University and the Massachusetts Institute of Technology have arranged to combine their forces in support of engineering education, may have a broad bearing on the future of engineering schools in this country. It suggests a tendency toward consolidation or concentration of educational forces, rather than further division and duplication. Universities and colleges are not efficient institutions when regarded from a business point of view. There is too much duplication of plant and staff, frequently accompanied by insufficient resources to make the work effective. This results in a struggle for existence that handicaps the institution and its students.

With this entering wedge already made in the East, it is likely that its effect will gradually be felt in the West and cause a much needed readjustment among western schools. The State largely supports university and college education in the West. In some of the commonwealths there has been a deplorable duplication of work, that puts a needless burden of taxation on the citizens. Colorado, for example, has a State University, School of Mines and Agricultural College, each teaching some branches of engineering. Washington has a State University and State College; Utah, a State University and Agricultural College; Oregon and Montana each maintain two, or, possibly, more, separate institutions, and so on through the list.

In all of these States the legislatures are called upon to appropriate funds for the maintenance and extension of two or more schools; and it seems inevitable that, from purely economic considerations, consolidation and concentration of effort will be forced on western schools. At present there is needless duplication in administration, instruction and equipment, and each institution is constantly, and quite naturally, increasing its demands on the State. The cost of education per student is needlessly high, for attendance is divided and equipment is multiplied.

The example furnished by Harvard and Technology probably will bear fruit elsewhere, East as well as West. From the larger point of view, the idea of consolidation is excellent, even though it entails sacrifice of individuality. The results ought to be a higher standard of engineering and a greater efficiency among future engineers. If western schools can agree on a scheme for cooperation they will have the satisfaction of working out their own salvation instead of having it forced upon them.

The Changing Character of Rail Steel

A few years ago it became evident that the ordinary Bessemer steel rail was doomed. The statistics of rail production in 1913, made public within the past fortnight, furnish conclusive evidence that alloy-cleared Bessemer steel has so far failed to save the situation for Bessemer steel. It still remains to be seen whether the electric refining process may not save the Bessemer rail. The electric steel rails at present in track have stood very well so far, but it would seem that some reduction in cost of the electric treatment was needed to encourage the railroad companies to become buyers.

In 1909 it became clearly established that the plain Bessemer rail could not survive as anything more than a subsidiary product. In 1907 the proportion of Bessemer to total steel rails was 93 per cent; in 1908 it was 70.3 per cent, and in 1909 it was 58.5 per cent, showing a rapid and irresistible trend. In 1912 the proportion was 34.4 per cent, while in 1913 it had dropped to the almost negligible proportion of 24.4 per cent.

The decadence is still more emphatically shown by the observation that of rails weighing 85 lb. and over per yard the proportion of Bessemer in 1913 was only 12.2 per cent. The standard rail of the future, of course, promises to weigh more than 100 lb. rather than less.

As to alloy-treated steel rails the following statistics of production in gross tons are very illuminating:

	Open-hearth.	Bessemer.	Total.
1909	13,696	35,699	49,395
1910	27,389	229,935	257,324
1911	38,539	115,450	153,989
1912	40,393	108,874	149,267
1913	33,567	25,952	59,519

The total of alloy rails was a maximum in 1910, there being a rapid decrease whereby three years later the quantity of such special rails was diminished to less than one-fourth of the 1910 total. Of additional significance is this fact, that while in 1910 practically nine-tenths of the rails alloyed or titanium treated were Bessemer, in 1913 less than one-half of the greatly diminished quantity was Bessemer.

The regular alloy rails are given as manganese, copper and nickel, electric rails being included in the statistics whether alloyed or not. In 1909 there were 35,945 tons titanium-treated, but the statistics do not show the division between Bessemer and open-hearth. Beginning with 1910 the titanium rails are shown separately as to Bessemer and open-hearth, and the figures again show a strong decline for Bessemer rails.

Within a few years the possibility of reviving the Bessemer rail by the discovery of a new process will have been greatly reduced, because the Bessemer equipment, which originally involved the expenditure of millions of dollars, is itself disappearing. One by one the great Bessemer steel plants have been modified, by actually dismantling the converters, by resorting to duplexing, or by the addition of open-hearth furnaces which would supply at least part of the steel for the attendant rolling mills. The last to yield has been the great Edgar Thomson works in the Pittsburgh district, in which plant fourteen large open-hearth furnaces have been installed in the past year.

Last year's total rail production was 3,502,780 tons. While this showed a gain of 5.2 per cent over the previous year, there were three years, 1906, 1907 and 1910, which showed a larger production than 1913, and the largest year of all was 1906, with 3,997,887 tons. Thus in seven years the rail industry has failed to make a new tonnage record. Such a lapse is not a new thing in rail manufacture, for in 1887 there was produced 2,139,640 tons, and it was not until 1899, twelve years later, that a new record was made.

Even the export trade in rails does not make a particularly good showing. It is true, 1913 made a new record, with 460,553 tons to its credit, but as long ago as 1900 there was exported 361,619 tons. Included in the 1913 exports was 161,971 tons shipped to Canada, against only 25,341 tons in 1910.

Rail exports apart from Canadian have really decreased in the most recent years, and it is fairly plain that very large exports to Canada cannot be continued. Canada is building railroads at a rapid rate for the moment, but the demand is probably temporary and it is doubtless for that reason that Canada does not establish sufficient rail-making capacity of her own to supply the demand.

Readers' Views and Comments

Quotations from Classics

To the Editor of Metallurgical & Chemical Engineering:

SIR:—It grieves me very much to feel compelled to criticise Mr. Woolsey McA. Johnson's article in the current number of your journal. On page 167 Mr. Johnson makes a grossly inaccurate quotation from that great English classic, "Alice Through the Looking Glass." While I fully realize the difficulty of making correct quotations from memory and while errors may be excusable in the case of relatively obscure and inaccessible literature, I fear that if something is not done your pages will shortly be disfigured by incorrect quotations from Shakespeare and the Bible.

FRANCIS A. J. FITZGERALD.

Niagara Falls, N. Y.

* * *

To the Editor of Metallurgical and Chemical Engineering:

SIR:—I have read Mr. FitzGerald's letter. I could have wished that he criticise the article in more important parts. The quotation is as follows:

"The walrus and the carpenter were walking close at hand. They wept like anything to see such quantities of sand. If this were only cleared away, they said it would be grand."

"If seven maids with seven mops swept it for half a year, 'do you suppose,' the walrus said, 'that they could get it clear?'"

My use of the above was, of course, merely in nature of a paraphrase and no pretence to accuracy was made.

WOOLSEY MCA. JOHNSON.

Hartford, Conn.

Keeping an Electric Furnace Hot During Periods of Idleness

To the Editor of Metallurgical and Chemical Engineering:

SIR:—In my article on the Stassano electric steel furnace at Redondo, Cal., in the December, 1913, issue of this magazine, it was stated that another furnace of the same type was being built in an Eastern foundry. This latter furnace has been in operation for some time at the works of the Hess Steel Castings Co., of Bridgeton, N. J., and results equally as good as at the previous installation are reported.

The furnace is an exact duplication of the one running in California, and we refer to the description and pictures of it in the above-named article in the December issue.

One new and economic feature in the operation of the furnace, however, is of especial interest. Slackness in business made it possible to turn out only one heat per day, and for some time only one heat every other day. The question arose how to keep the basic magnesite lining hot during the long intervals at a minimum expense.

Heretofore the Stassano furnaces running in daytime only have been kept hot nights and during the Sunday idleness by electricity, which method involved a considerable expense for current, electrodes, and labor. In this new installation, however, an arrangement was made to keep the furnace hot by means of an oil burner, cutting down the cost to a small fraction of the former cost for electricity, and entirely eliminating the cost of electrodes and labor, as the oil burner needs no attention whatever. A similar arrangement

has been worked out independently for the California furnace.

The small steel foundries, which could not take care of the total output of five tons for 24 hours of the one-ton type of Stassano furnace, or which for some other reason wanted to avoid working a night shift, will be highly interested in the fact that they can now run a furnace of this type in daytime only with two or three heats, at only a nominal expense for heating. In many instances the foundry gains the added advantage of keeping off the peak load of the power company supplying the current, and thereby enjoying a cheaper current rate.

ERNEST M. SCHMELZ.

Detroit, Mich.

Efficiency and Refining Possibilities of the Induction Furnace

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In your February issue, page 74, Mr. Ivar Rennerfelt is good enough to draw my attention to the fact that the original statement in my article "Induction Furnace Notes" of October, 1913, was correct and not an error as stated in the December issue, 1913.

As Mr. Rennerfelt assumes, the expressions "melting hours" and "kilowatt hours" (units) have been mixed up, as I find by looking up the melting records. I, therefore, wish to thank Mr. Rennerfelt for drawing my attention to the mistake.

An electric efficiency of 67.1 per cent, however, is certainly not unattainable in a two-ton furnace; I have on record an efficiency of well over 71 per cent in an even smaller furnace having a capacity of only 850 kg.

But it should be borne in mind that the expression "electrical" or "theoretical" efficiency is a very deceiving one.

As is well known generally, steel is not made by simply melting down scrap; even at its best it must also be purified from gases, oxides, etc., and the figure of 63.8 per cent includes all power spent for such purposes.

The economical efficiency is, to my mind, the only important factor, as is also emphasized in the subsequent paragraph of the article.

As to the refining question, it is well known and has often been repeated both by myself and others that the single-ring induction furnace, with its narrow channel and small bath surface, is not intended to be used for the removal of sulphur and phosphorus, but in many respects it is an ideal melting furnace and is therefore recommended as such.

It was this I had in mind when the statements quoted were made.

The "combination" induction furnace of the Rodenhauser type, however, to which Mr. C. H. Vom Baur no doubt was referring in his article, and which I also have had many opportunities to watch, has very good refining possibilities on account of its enlarged central hearth and larger bath-surface.

So has also the double-ring induction furnace designed by Mr. O. Frick.

It is not my intention to enter into a controversy as to the relative merits or disadvantages of arc furnaces and induction furnaces; both have their fields and if one is asked to recommend one or the other, as is frequently the case, the answer must be made solely with the purpose in view for which the furnace is intended, disregarding any sentiment in favor of one or the other.

Special conditions, as regards the work to be carried out, the locality, the available electricity supply, the question of continuous or intermittent operation, etc., must be carefully considered in each individual case before one is able to recommend one system or the other.

An open discussion, such as Mr. Rennerfelt suggests, would no doubt be of general interest. But it is very questionable whether it would lead to any so-called final decision. Both systems will no doubt continue to live side by side, as past experience seems to indicate.

Only the most careful consideration of each individual case and a full knowledge of the merits and possibilities, as well as the drawbacks and limitations of the various furnace types, will enable the engineer and metallurgist to make up his mind which type is most likely to be successful in his particular case. JOH. HARDEN.

Luton, England.

* * *

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Mr. Rennerfelt's communication appearing in your February issue is very interesting. No doubt what Mr. Harden had reference to was a single-ring induction furnace of the Kjellin type. My own experience with furnaces of this kind has confirmed that it is impractical to endeavor to refine steel with the usual slags in a single-ring and narrow-channeled induction furnace.

However, all these furnaces had to have their beginning, and it is now over a dozen years ago that Kjellin first placed an induction furnace in regular commercial operation. It is now over seven years that the first wide-hearthed induction furnace was placed in operation, and one is now under construction with a bath the exact proportions of an open-hearth of corresponding size. The induction furnace will soon be in its early manhood, with the progress now going on.

To return to the refining—as soon as a two-ring induction furnace was placed into practical operation, it was demonstrated that any degree of refining of phosphorus and sulphur and general degasification could be obtained. A curve taken from Rodenhauser's and Schoenawa's book on Electric Furnaces in the Iron and Steel Industry, page 399, shows that the phosphorus dropped from 0.06 to 0.025 per cent. in the first 20 minutes, while the desulphurization was from 0.065 per cent. to traces in somewhat more than an hour. The general deoxidation or degasification is exemplified by the excellent physical qualities of tool steel—about 57 varieties—not to mention rail steel and others, made in the 8 to 10-ton Roechling-Rodenhauser furnace, charged with liquid basic Bessemer steel.

There are as many induction furnaces to-day in Germany as there are arc furnaces, so that favoritism is at least evenly divided, even though the induction-furnace installations are usually more expensive for the same size, than their arc-furnace brothers.

At Kladno, the Poldihuette after using a 4-ton Kjellin furnace, single-ring type, for about 6 years is installing an improved design of induction furnace of 13 tons capacity. One of the large iron works of Eastern Pennsylvania is installing two 20-ton induction furnaces. Krupp at Essen has two 10-ton induction furnaces in regular operation, so whatever their "practical drawbacks" are, their virtues are enough to overcome them as the repeat orders indicate. The induction furnace is a very rugged child in the electro-metallurgical industry just now, even though it was a little dwarfed in its infancy.

C. H. VOM BAUR.

Douglaston, N. Y.

Concentration of Complex Sulphide Ore from the Mary Murphy Mine

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In the issue of your magazine for March, 1914, page 157, Mr. Dyke V. Keedy has contributed a rather elaborate discussion on the concentration of complex ore from the Mary Murphy mine, based on my original article on the same subject in your January issue. It is personally gratifying to think that Mr. Keedy should have analyzed the article in such detail, but it seems to me that he set for himself a laborious task, the results of which are of little or no value, due to the fact that he draws conclusions from incomplete data and from assumptions of his own. That the data were incomplete is scarcely a legitimate criticism of the original article, for it was not an engineering report on the efficiency of the Mary Murphy mill, based on a related series of tests and investigations, but a description of operations by a visitor, with occasional figures and tabulations to show the results obtained. There is every reason to believe the general accuracy of the data given; but it is obvious that the figures were not such as would justify an attempt to make the checks and calculations submitted by Mr. Keedy. As a consequence, the fallacy of much of his contribution lies in the assumptions he has made and substituted for unstated facts.

In the first place, the weights of products (lead concentrates, zinc-iron middlings and zinc slimes) are not actual net dry weights, but the total of daily estimates made by the mill operatives on moist products, which estimates usually are well on the safe side. As a matter of fact, the actual shipments of lead concentrates credited to September operations totalled 161.62 tons, as against the daily estimates of 138 tons. The estimated tonnage should not be used in such calculations as Mr. Keedy has made, and probably he would have been spared his trouble if I had explained them more fully. Being merely estimates taken from the daily operating sheets, they might properly have been omitted. Since the weights of recovered products are not accurate, the assumed weight of tailing also is inaccurate, being estimated by difference; and the re-calculated recoveries cannot stand, being based on assumptions. Furthermore, in calculating the gold recovery, Mr. Keedy assumes all amalgam as gold, thereby making even his reduced saving too high.

The method of calculating recoveries from head and tailing samples is criticized as "incorrect and misleading because of the very important fact that the large quantity of water used on the jigs and tables, and running to waste therefrom, carries unseen and frequently unnoticed an unknown quantity of mineral values." At the Mary Murphy mill the tailings from all concentrators are combined before leaving the plant, so that a fair sample of general tailing is taken. The quantity and value of suspended matter in the tailing water, escaping collection, is not as great as one would think, especially if some precaution is taken to assist settlement in the sample. Thus, on one occasion, 500 lb. of water was decanted from a settled tailing sample and evaporated to dryness. Only 2 oz. dry slime, or 0.025 per cent., was recovered, containing a trace of gold, 1.4 oz. silver per ton, 4 per cent. lead and 18.7 per cent. zinc. When one remembers the ratio of water to solids in tailing, about 15 to 1 in this case, the loss in suspended matter is seen to be inconsiderable, and a tailing sample prepared in this way forms a good basis from which, together with products, to calculate recovery.

Mr. Keedy prefers to omit from zinc and lead "recoveries" that portion of those metals contained in lead and

zinc concentrates, respectively, because he says they bring no economic return and may even entail penalties. I think he understood, however, that the "recovery" figures I gave represent metallurgical saving and not economic recovery. A knowledge of the smelter contracts on the various products would be necessary to determine economic recoveries and losses, as well as possible penalties. Unquestionably loss is suffered, but it cannot be determined by assumptions. It is generally recognized that metallurgical saving and economic recovery on such an ore are not synonymous.

In regard to the electrostatic work, the failure to give weights of products in my tabulations is an omission, for they were placed at my disposal. Mr. Keedy is quite right in assuming that the assayer's figures are reliable, but he falls into a pardonable error in attempting to check up the gold in the various products from Mary Murphy ore. Weights would have been of little value in such an effort, and might have made the problem more perplexing. It is my understanding that close accounting for gold is considered one of the impossibilities at the Mary Murphy; in the mine, in the mill, and almost equally in the smelter settlements, it is strictly where you find it, and not always where it ought to be. Referring to the retreatment of electrostatic middlings, which Mr. Keedy says "resulted in a net loss," I will say that the table of figures was given for the very purpose of showing how unsatisfactory the experiment proved.

Touching on the criticism of the regrinding practice. Mr. Keedy's suggestion to by-pass the slime contained in tube mill feed is perhaps pertinent. But in objecting to too-fine grinding of the entire pulp he must not forget that the character of Mary Murphy ore is such that fine grinding is required to liberate gold, even though base minerals are slimed in the operation. It is a question of economic operation. I presume that the management of the Mary Murphy is cognizant of the value of gradual reduction in size, in concentrating such an ore. Perhaps a few months' experience at the mill would reveal to Mr. Keedy many practical difficulties which cannot be appreciated otherwise. A clearer insight to the situation will be gained by reading an article by Mr. George E. Collins, manager for the Mary Murphy company on page 243 of this issue. It furnishes many interesting details relating to the mill practice.

Denver, Colo.

H. C. PARMELEE.

Pyrophoric Alloy Patent Decision

In the suit of the Treibacher Chemische Werke (Gesellschaft mit Beschränkter Haftung) vs. The Roessler & Hasslacher Chemical Company, a decision has just been rendered in the District Court of the United States, Southern District of New York. The decision which is written by Judge Hough is in favor of the complainant. The patent in question, No. 837,017, issued to Welsbach on Nov. 27, 1906, and assigned to the Treibacher Chemische Werke, is held to be valid as a pioneer patent and to be infringed.

From Judge Hough's decision we quote the following:

"The only claim involved is this: 'A pyrophoric alloy, containing cerium, alloyed with iron; substantially as and for the purposes described.'

"The 'purposes described' in the specification render plain the contest before the court.

"The patentee tells the world that all preceding investigators were wrong in supposing that the so-called 'rare-earth' metals, when pure, possessed pyrophoric capacity, i.e., the property when abraded of giving off particles self-igniting in the air.

"Admittedly these metals, and especially cerium, had

long been called pyrophoric, but Welsbach deems himself the first to discover that the spark-giving quality depended on impurities whose presence had before him been unobserved, or if noted considered negligible.

"It is not pretended that this ascertainment of a natural phenomenon constitutes patentable invention.

"Since, however, the cerium ordinarily obtainable had been known to give forth sparks and abrasion, Welsbach says he sought to ascertain what kind of mixture would produce sparks in greatest abundance. Iron afforded the best results, and an alloy of cerium 70 per cent and iron 30 per cent the maximum pyrophoric effect.

"The sparks elicited are not different from those known to have been drawn from the 'rare-earth' metals as produced from Welsbach's experiments, but the flow from his alloy is said to be so copious and certain as to furnish a 'prompt and reliable' means of igniting 'combustible gases mixed with air.'

"The patentee experimented with 'certain other metals,' and mentions nickel and cobalt as possible ingredients in his alloy, but iron remains the favorite. On alleging as true the substance of the foregoing the patentee sought and obtained the wide claim above quoted.

"Defendant has imported and sold a substance manufactured by Kunheim & Company, of Berlin, said to be composed (in accordance with specification of Huber, U. S. Patent 967,775, Aug. 16, 1910), of magnesium, 15 per cent, and cerium, 85 per cent, treated with hydrogen at between 500 deg. C. and 600 deg. C., as long as any absorption of hydrogen can be detected. The magnesium-cerium compound is pyrophoric, the alleged effect of absorbing hydrogen is to increase that quality.

"The defence asserts:

"(1) Welsbach's invention to be void for lack of novelty, i.e., it covers only a 'pre-existing inherent natural property of the alloy.'

"(2) Kunheim's product is not an alloy at all, and therefore not an infringement.

"(3) The claim in suit is (in view of the prior art) too narrow to cover any alloy not containing substantially the preferred quantity of iron—or possibly nickel or cobalt.

"First: This defence will not stand analysis. It is true that great pyrophoric activity is, and always must have been, an inherent natural quality in an alloy of iron and cerium. It is also true that any composition of matter has inherent natural qualities—but before such qualities can be known and used—the matter composition must be produced. Nature does not produce the alloy of Welsbach, and if that alloy is novel and artificial, the compound is patentable as far as novelty is concerned.

"Second: The dictionary meaning of alloy is 'an artificial compound of two or more metals combined while in a state of fusion.' The important words (for this case are, *two or more metals*, and all the experts examined agree that an alloy must contain that number.

"Admittedly both magnesium and cerium are metals, and the best and sufficient evidence that defendant's product was once (at all events) an alloy, is that Huber calls it one, and defendant insists that what Huber describes—it sells.

"But it is said that the hydrogen bath has created a cerium hydride, which is something so different from a mere alloy of cerium and magnesium as to be a different thing, i.e., a chemical compound of admittedly uncertain properties and formula.

"On such a point as this I am as far as possible from hazarding any opinion other than one as to the weight of evidence. I see no reason to doubt the facts testi-

fied to by Drs. Fettinger and Olsen, i.e., that they made an amalgam of the alleged infringing substance, and liberated the hydrogen, thereby demonstrating that the hydrogen was physically not chemically combined with the cerium and magnesium. It seems to me that what Huber called an alloy, so remained, even though saturated (so to speak) with hydrogen.

"Third: The substantial question in this case is that of infringement, and that depends on the range of equivalents, permissible to the patentee"

The decision then takes up the requirements of a "pioneer patent."

"Whether any given invention is a 'wholly novel device' or one of 'such novelty and importance as to mark a distinct step in the progress of the art' always and principally depends on how much men knew before they learned what the patentee taught.

"Before the disclosures of Welsbach it is, I think, shown that men knew nothing of the certain and reliable preparation or manufacture of a pyrophoric alloy. They thought they knew that cerium was pyrophoric, whereas they had merely observed sparks given out by an impure metal, without connecting the impurities and sparks, as cause and effect.

"Before Welsbach there was and could be no *art*, in pyrophoric substances, because the basis of all art, certain knowledge, was lacking. This patentee taught how certainly and knowingly to produce that which had been observed indeed, but not understood. Such invention is indeed pioneer.

"The argument against the above conclusions rests upon several patents, and the disclosures of numerous scientific publications.

"One good reference or publication is worth more than a volume of poor ones, and I select the German patents to Escalés, the article of Hillebrandt and Norton and Moissan's article in *Der Elektrische Ofen* as covering the whole defence."

These are briefly reviewed by the Court and it is said that "Moissan is much nearer the point in his opinion (*meiner Ansicht*) that it would be better to use (for fire-making apparatus) 'an alloy of iron with uranium,' but he never did it, and he did not tell anyone just what to do.

"Prophecy is often greater than invention, but it is not patentable.

"Believing then that this is a pioneer invention, can the doctrine of equivalents be invoked to read the claim in suit, an *alloy* of cerium with any other metal, provided that such alloy be pyrophoric?

"On this head the first inquiry is whether the patentee has tied his own hands, by limiting his claims. Groth vs. International &c. Co., 61 Fed. Rep., 284.

"Such is asserted to be the case here, for iron only is mentioned in the claim; but the inventor shows that the cerium is to be alloyed with iron or its equivalent (line 67), so that the final question is what are the equivalents of iron in a pioneer patent, when the specification shows that the invention is far wider than the use of iron only.

"As has been often said, where a valuable invention has been made it is the duty of the Court to uphold that which was really invented.

"What Welsbach invented was a metallic alloy having certain desirable qualities—he knew and said that iron was not the only (though it was the most desirable) component with cerium.

"If a metal other than iron be used, does the resultant embody Welsbach's invention? This is the root query.

"The question is one of fact, not law, and the innumerable cases on equivalents are merely statements of how the minds of sundry judges have worked when sitting as jurymen.

"To me it is obvious that the usefulness of an alloy, i.e., a fusion of metals, was Welsbach's plainly disclosed invention—without knowledge thereof Huber would not have known that it was useful to make an alloy of magnesium and cerium, therefore, he used and uses Welsbach's invention and is an infringer."

The Brown Cyanide Patent Decision on Appeal

In our issue of October, 1913, page 541, reference was made to the Brown cyanide process patent decision, by which in the United States District Court for the District of Delaware (Judge Edward G. Bradford) the Tonopah Mining Company was found to have infringed a patent of Alden H. Brown. This decision has now been reversed by the United States Circuit Court of Appeals for the Third District (Judges Gray, Buffington and McPherson) and the case remanded with instructions to dismiss the bill for non-infringement.

Brown's patent has special reference to the sequence of several steps by which the metals are recovered by cyanidation and concentration. Customarily an ore requiring both concentration and cyanidation is subjected to the treatment in the order mentioned. Brown's patent covers the reverse method, viz., cyanidation followed by concentration. His second or broad claim reads: "A process of treating sulphide ore consisting first in subjecting the raw or unroasted ore to the action of a cyanide solution whereby the finer metallic values are dissolved, and second, subjecting the ore or tailings to concentration whereby the coarser values are recovered."

In the decision of the Court of Appeals, written by Judge Buffington, Brown's invention is analyzed at some length.

"It will be noted that no new principle of operation, either in cyaniding or concentrating themselves was disclosed in this patent. It was at most simply a more effective treatment and it will thus be seen that transposition of concentration from initial to final stage, and of cyanidation from final to initial stage is the substantial disclosure of this device. Assuming, for present purposes, that this change was original with Brown, and that it involved invention it must be conceded the field of invention was narrow, and Brown's claim should not by construction be enlarged to include within infringing fences processes which were not within the field of his inventive disclosure. Not without entering into details it suffices to say that the second claim embodies the two elements of, first, cyaniding, viz., 'subjecting the raw or unroasted ore to the action of a cyanide solution whereby the finer metallic values are dissolved,' and, second, concentrating, viz., 'subjecting the ore or tailings to concentration, whereby the coarser values are recovered.' This claim is perfectly clear. A reading of the patent shows precisely what the patentee disclosed, and the claim precisely claims that disclosure. There is no ambiguity in either disclosure or claim. They are self-sufficient and self-explanatory.

"This two-staged process, first, cyaniding; next, concentrating, being the only disclosure of Brown and the claims embodying these two separate, individual, completed stages or steps, it follows that any process which makes concentration an intermediate and completed step, one that precedes final and effective cyaniding, is a process different from the one Brown disclosed and claimed. Measuring the defendant's process by these standards, it follows that infringement is not shown, for, without entering into a detailed description of its plant, it suffices to say that a study of its workings has brought us to this conclusion. The defendants, in com-

mon with Brown, it may be conceded, are using the cyanide solution in the earlier stage of their process, and to that extent we may say initially utilize the general chemical treatment incident to cyaniding, preparatory to concentrating. But beyond this the resemblance ceases, for by defendant's process concentration—effective, finished and final—is the initial and intermediate step in their process. At such intermediate step the fruits of concentration are withdrawn from the process, and this first completed step of the process, the one 'whereby the coarser values are removed,' is, as we have seen, the second step of Brown's process.

"After the defendant's concentration is finished, the by-product goes forward to be subsequently treated by a protracted process of cyaniding. This is at variance with Brown's process in three respects, first, cyaniding follows concentrating; second, it is a system condemned by Brown and one he sought to avoid in that where 'concentration . . . is used preliminary to the cyanide process it will be necessary to have a very

coarser values, which are readily recoverable by concentrating, the latter being specially adapted for saving this class of values.'

"It is apparent, therefore, that the defendant's device, which the proofs show has been of great practical worth, owes its worth to the fact that it is built and operated in express disregard to the instructions of Brown's patent. Without passing on the question of the validity of that patent it suffices to hold defendants do not infringe."

Presentation of the Bronze Bust of the Late Morris Loeb to the Chemists Club

At a meeting of the New York Section of the American Chemical Society, held in the Chemists' Building, New York City, on March 6, 1914, a bronze bust of the late Morris Loeb was dedicated and presented to the Chemists Club.

Dr. L. H. Baekeland, in his speech of presentation, sketched the ideals of Morris Loeb and his work for chemistry in America and for the Chemists' Club. Dr. Baekeland concluded as follows:

"After his untimely death, which left so many in sorrow, it was found that by his will Morris Loeb had planned the realization of the ideals he had preached.

"To his university, Harvard, he left a large sum of money for chemical research; to the Chemists' Building, he gave all his shares; to the American Chemical Society, he left a fund for the creation of a chemical museum along the lines conceived and clearly described by him.

"None of us, who have known Morris Loeb, who have lived, worked, or spoken with him, need a bust nor a portrait to remind us of the man or his work. But as we grow older and death keeps thinning out our ranks, younger generations of chemists will use these halls. Our duties, our responsibilities will become their duties, their responsibilities.

"I have no doubt that their aims for good will be of the highest; that they will better realize than the present generation that to be a chemist is to be an apostle of progress and civilization, of justice and truth.

"But the chemists of the coming generation will not have known Morris Loeb, and we must remind them of what one of our generation dreamt, planned and did for them.

"This is the reason why some friends of Dr. Loeb obtained a bronze bust from Mr. Karl Bitter, an artist whose reputation is no longer to be made.

"It is their desire that this bust should adorn the halls of the Chemists Club.

"Dr. McKenna, upon you, as president of the Chemists Club, devolves the responsibility of placing this bust where it will best serve its purpose."



BUST OF MORRIS LOEB

extensive system of settling tanks in order to recover these suspended values and hold them in the mill so that they may be subjected to further treatment'; third, the defendant's process which physically withdraws from the operation of the process the products of concentration in advance of withdrawing those of cyaniding, makes the process one avoided by Brown, viz.: 'It is a well-known fact that the cyanide process recovers only the fine values and in the treatment that I have devised these fine values are recovered by the cyanide process in the beginning, leaving only the

The preliminary report on mineral production in Canada in 1913, by the Dept. of Mines, shows a total value of production in the year just closed of \$144,031,047. Although estimates have been made in some cases where complete returns were not available, it is probable that the final record will be a revision upward. The total value of the production in 1912 was \$135,048,296, compared with which the 1913 output shows an increase of \$8,982,751, or 6.65 per cent. In view of the large increase over all previous years made in mineral production in 1912 and the general trade depression and industrial restriction experienced during the latter part of 1913 the industry would appear to have made in the aggregate very satisfactory progress. The average production per capita in 1913 was \$18.57, as against \$18.27 in 1912 and \$14.93 in 1910.

Program of New York Meeting of American Electrochemical Society

The twenty-fifth general meeting of the American Electrochemical Society will be held in New York City on Thursday, Friday, and Saturday, April 16 to 18.

The headquarters will be at the Chemists' Club, 52 East Forty-first Street. There will be technical sessions on the morning and afternoon of Thursday in Rumford Hall in the Chemists' Building, 50 East Forty-first Street, and on Saturday morning and afternoon in Earl Hall, Columbia University. There will be a smoker on the evening of Thursday in Rumford Hall, Chemists' Building, and a dinner-dance on Saturday evening also in the Chemists' Building.

On Friday there will be an all-day excursion by steamboat around New York Harbor and Staten Island combined with visits to the plants of the American Smelting & Refining Company, the United Lead Company, and the Waclark Wire Company. The arrangements for the meeting are in the hands of the New York Section of the American Electrochemical Society, and the smoker on Thursday night and the steamer party on Friday are complimentary affairs tendered by the New York Section.

The program of the technical sessions is as follows:

Thursday, April 16, 9 a. m., Rumford Hall, Chemists' Building: Annual business meeting, followed by Symposium on Power Problems in Electrochemistry:

C. P. Steinmetz, Characteristics of Electrical Energy as Affecting Chemical Industries.

P. Sothman, Efficiency of Power Transmission Versus Utilization in Local Electrochemical Industries.

F. A. J. Fitzgerald, Economics of Electric Furnace Operation.

W. S. Horry, Power Supply to Electric Furnaces.

Lawrence Addicks, The Power Problem in the Electrolytic Deposition of Metals.

H. E. Longwell, The Power Problem in the Electrolytic Deposition of Metals.

F. D. Newbury, Sources of Direct Current for Electrochemical Processes.

General discussion.

Thursday, 2 p. m., Rumford Hall, Chemists' Building:

Wilder D. Bancroft, Electrolytic Flames (An Experimental Lecture).

C. A. Hansen, Electric Steel Castings.

Eugene B. Clark, Electric Furnaces for Steel Making.

G. C. Stone, Improvements in the Metallurgy of Zinc.

W. R. Ingalls, Electric Zinc Smelting.

W. P. Lass, Advantage of Southeastern Alaska for Hydro-electrochemical Industries.

Thursday, 8 p. m., Rumford Hall, Chemists' Building:

E. F. Roeber, Some Economic and Aesthetic Aspects of Electrochemistry (Presidential Address).

Thursday, 8.45 p. m., Smoker.

Saturday, 9 a. m., Earl Hall, Columbia University:

E. A. C. Smith, Progress in Leaching and Electrolytic Treatment of Copper Ores in South America (A Lecture).

R. R. Goodrich, Hydro-electrometallurgy of Copper.

Rudolph Gahl, Leaching of Copper Tailings.

Ralph W. Deacon, Metal Inventory in an Electrolytic Copper Refinery.

Joseph W. Richards, Electrolytic Zinc.

O. P. Watts and A. C. Shape, Addition Agents in the Deposition of Zinc from a Solution of Zinc Sulphate.

Frank C. Mathers and O. Ralph Overman, The Effect of Addition Substances in Lead Plating Baths.

Frank C. Mathers and Hugh M. Marble, Electrodeposition of Cadmium.

C. W. Bennett, H. C. Kenny and R. P. Duglass, Electrodeposition of Nickel.

C. W. Bennett and A. W. Davison, Electrolytic Deposition of Brass on a Rotating Cathode.

Gustave E. F. Lundell, A New Method for the Determination of Free Cyanide in Electroplating Solutions.

Saturday, 2 p. m., Earl Hall, Columbia University: E. F. Northrup, Electric Conduction at High Temperatures and Methods of Measurement (An Experimental Lecture).

F. A. J. Fitzgerald, Laboratory Notes on Some Electrical Properties of Silver Sulphide (with experiments).

Claude N. Hitchcock, Polarization Single Potentials.

Reinhard Beutner, New Cell Arrangements for Direct Determination of the Free Energy.

R. Stuart Owens, Experiments on White Lead.

Oliver W. Storey, A Microscopic Study of Electrolytic Iron.

O. P. Watts and M. H. Li, The Effect of Addition Agents in the Electrodeposition of Iron.

O. L. Kowalke, Base-Metal Thermocouples and Their Microstructure.

Saturday, 7 p. m., Subscription Dinner, followed by Dancing, at the Chemists' Club.

The arrangements of the meeting are in the hands of the New York Section, of which Mr. Lawrence Addicks is the chairman and Mr. H. B. Coho (United Lead Company, 111 Broadway, New York City) is the secretary.

The Western Metallurgical Field

Flotation and Cyaniding

Flotation processes have been used mainly with the object of producing from ores a marketable concentrate for subsequent smelting. Low-grade zinc and copper ores are thus treated quite extensively. Another possible field for flotation, which has not received very much attention, is the concentration of gold ores, with the idea of cyaniding the concentrates thus produced. Some preliminary work along this line has been done by Mr. Justin H. Haynes, and the proposal seems worthy of consideration in cases to which it is applicable. The type of ore most amenable to such a process would be a simple pyrite in silicious gangue, the gold and silver being contained wholly or mainly in the pyrite and not distributed through the gangue. From this ideal condition we might extend the process to ores containing some galena also; but the principal point to be observed would be the association of the precious metals with the sulphide constituent, so that on floating the concentrate the tailing might be discarded as worthless.

The rejection of sand tailing characterizes some present operations in which tagle concentration plays a part. Thus at Cripple Creek, the Portland company first concentrates the ore, removing sulpho-tellurides, and then classifies the remaining pulp into sand and slime, discarding the former. A similar procedure was in effect at Idaho Springs when the Hudson mill was running. Of course, there are districts in which the nature of the ore will not permit the rejection of the sand.

Flotation, however, might offer some advantages even in the cases cited, for it would recover in one concentrate the slime mineral as well as the coarse which is now caught on tables, and thus render the slimy as well as the coarse gangue without value. We would then have for treatment by cyanidation only the concentrate, which would be but a fractional part of the crude ore. The cyanidation of concentrates is practiced in numerous places. Where this is possible, flota-

tion would be an excellent means of first getting all the mineral in a concentrate of high grade. The cost of cyaniding and the metallurgical losses sustained in that process would then be greatly reduced when calculated per ton of crude ore, and certain refinements could be introduced that would be prohibitive if applied to original ore. The object of flotation would not be the production of a marketable concentrate, containing as little gangue and as much mineral as possible, but primarily to get all the mineral, even though it was accompanied by more gangue than would be permissible if the concentrate were to be smelted. The cost of the cyaniding plant would be greatly reduced, as also would that of the concentrating department, and a mill based on such a process might come within the means of companies owning small mines.

Smelters and Farmers

Rumor has been current to the effect that the farmers of the Tooele district in Utah expect to make trouble for the International Smelting & Refining Co., which has a large copper and lead smelter there. It is unlikely that such will be the case, or at least it seems so in view of the elaborate precautions taken by the company before the smelter was located there and before operations were commenced. At that time the company had experts in the field making observations on the condition of the flora of the region, with special reference to agricultural and horticultural crops. It is understood that the company at that time took options on much of the land, with the intention of buying them if the farmers preferred to sell. Under these conditions it seems doubtful if the farmers could present a good case, and it is likely that many of them will care less about litigation when they find that the company stands ready to buy their land.

The situation in California is not so favorable to the smelters, and some interesting developments may occur there this summer. Incidentally it may be stated that experimental work with the Hall process of distilling and recovering sulphur from ores is proceeding, and that the early results are encouraging.

Chlorination Processes in Utah

Mention has been made previously in this column concerning the adoption of a process of chlorination at two mills in Utah: one at Park City, where the Mines Operating Co. is treating ore from the old Ontario; and the other at Silver City, where Jesse Knight is completing a new mill. Within the past month it has been announced that a third mill, also at Park City, is to adopt a similar process. The dry concentration mill formerly operated there by the Grasselli Chemical Co., treating zinc middlings, has been purchased by Salt Lake parties, and will be remodeled into a custom mill using a process based on chloridizing-roasting and leaching. Ore from the American Flag mine, among others, will be treated. The owners of this property have been making metallurgical investigations for some time, seeking the best method of recovering gold, silver, copper, lead and zinc, all of which exist in the ore in small quantities. We are informed that concentration has yielded poor results. A combination of concentration and cyaniding has done much better, but the process which has been adopted is said to have yielded by far the best results, with a probability of making a good recovery of all the valuable metals. The anticipated cost of treatment is given as \$3.50 per ton, and the recovery as over 90 per cent of all the metals.

Oil Flotation at Butte & Superior

According to a report filed by the Butte & Superior Copper Co. in the federal court, in accordance with the

court's order pending settlement of a suit brought by the Minerals Separation, Ltd., the company treated in January by flotation 29,188.9 tons of ore, yielding 7062.6 tons of concentrates. The cost of this part of mill operations is given as \$4.225 per ton, and the value of concentrate as \$23.45 per ton. About 88 per cent of the ore handled in the mill was treated by flotation. The following tabulation shows the results of flotation on that part of the tonnage thus treated.

	Heads	Concentrates	Tailings
Zinc, per cent.....	13.91	50.71	2.06
Lead, per cent.....	0.77	4.43	0.15
Copper, per cent.....	0.19	0.45	0.04
Iron, per cent.....	2.73	1.39	0.94
Manganese, per cent.....	1.44	2.72	0.85
Insoluble, per cent.....	68.87	10.82	91.50
Silver, oz. per ton.....	7.73	26.55	1.62
Gold, oz. per ton.....	0.02	0.05	0.004

Company Reports

The Arizona Copper Company, Ltd., has made public a report of its operations for the year ended September 30, 1913. The year's production of copper was 34,230,000 lb., being less by 3,920,000 lb. than for the preceding year. This decrease is partly accounted for by a lower grade of ore and by delay in getting the new smelting works in operation up to capacity. The ore mined from the company's properties yielded 38.76 lb. copper per ton, a decrease of 2.39 lb. per ton as compared with last year. During the year 780,887 dry tons of ore was concentrated, 68.7 per cent of the quantity being handled at No. 6 concentrator and the balance at the Clifton concentrator. The average ratio of concentration was 7.26 to 1. The work at No. 6 has been handicapped by reconstruction which has been under way. Hardinge mills have been substituted for Huntington mills. The works for treating oxidized ore by concentration handled 106,596 dry tons of ore, and 85,071 tons of tailings from this concentrator was leached. The copper recovered from oxidized ores amounted to 9.27 per cent of the total production. In the smelting department a total of 151,265 tons of ore and concentrates was smelted. The average yield of copper from material smelted was 11.31 per cent. The old smelting plant was closed on December 31, 1913, the new plant having been started in August.

From the report of the Mount Morgan Gold Mining Co., Ltd., Mount Morgan, Queensland, we excerpt the following items on operation as given by Mr. B. Magnus, general manager. The following table gives statistics from the reduction works for the six months ending November 30, 1913:

	Copper obtained, Tons	Copper, tons	Copper, per cent	Gold, oz.	Gold, dwts.
Copper ore.....	123,247.00	3,852.49	3.125	52,484.58	8,516
Many Peaks ore.....	25,632.00	336.63	1.312	198.26	154
Purchased ores..	45.77	7.75	16.932	60.80	26,567
Miscellaneous products	3,091.19	157.19	5.085	2,248.86	14,550
	152,015.96	4,354.06	2.864	54,992.50	7,235

The copper ore smelted assayed about 55.6 per cent silica, which is 3 per cent higher than for any previous period. This has entailed extra expense for fluxing material, and has added to cost of operation, as it costs approximately 6½d. (13c) per unit to flux silica. This points to the necessity of getting the concentrator in operation as soon as possible. When the latter is running, ore containing over 52 per cent silica will not be smelted direct unless it is high in gold content. Experimental work in concentrating has proceeded, and a representative of Minerals Separation has been on the ground to check up the work. The recovery is better than estimated, and the cost is less. Serious delay has been experienced in delivery of steel for the new smelter building, and has materially deferred the blowing in of the new plant. A Dwight-Lloyd sintering plant will be installed to handle flue dust.

"Skin Effect" in Carbon Electrodes

BY A. T. HINCKLEY

At the spring meeting of the American Electrochemical Society in 1912, Mr. Turnbull's paper on Furnace Electrodes gave rise to some discussion as to the magnitude of the "skin effect" in large electrodes. No one apparently had any figures on the subject, and the question was settled by the opinion of Mr. Hansen that the effect should not be large owing to the relatively high resistivity of carbon.

Since that time the question has come up several times whether or not carbons in the form of hollow cylinders would give longer life in electric furnace work, as the "skin effect" would be less in such carbons than in the solid cylindrical ones. As far as we know there have been no figures published concerning this up to the present time.

In the *Journal of the Franklin Institute* for February, 1914, Mr. Carson, working with Dr. Northrup at Princeton University, has given a mathematical treatment of the "Skin Effect and Alternating-Current Resistance" phenomena. From these data we have calculated the magnitude of this effect in 24-in. round carbon electrodes.

R_{ac} = resistance per unit length for alternating currents.

R_{dc} = resistance per unit length for direct currents.

The magnitude of the ratio $\frac{R_{ac}}{R_{dc}}$ is desired.

$$\frac{R_{ac}}{R_{dc}} = \frac{1 + c_1 \left(\frac{\mu f a^2}{\rho} \right)^2 + c_2 \left(\frac{\mu f a^2}{\rho} \right)^4 + \dots}{1 + \frac{c_1}{2} \left(\frac{\mu f a^2}{\rho} \right)^2 + \frac{c_2}{3} \left(\frac{\mu f a^2}{\rho} \right)^4 + \dots}$$

$$c_1 = 6.49 \times 10^{-5}$$

$$c_2 = 3.55 \times 10^{-10}$$

μ = permeability

f = frequency in cycles per second

a = radius of conductor in cm.

ρ = specific resistance per cm cube, in microhms.

For a 24-in. round carbon electrode used on a twenty-five-cycle circuit,

$\mu = 1$ (practically)

$f = 25$

$a = 30.48$

$$\rho = \frac{0.0020 \times 6.45 \times 10^6}{2.54} = 5100$$

$$\frac{\mu f a^2}{\rho} = \frac{1 \times 25 \times 30.48^2}{5100} = 4.54$$

$$\frac{R_{ac}}{R_{dc}} = \frac{1 + 6.49 \times 10^{-5} (4.54)^2 + \dots}{1 + 3.24 \times 10^{-5} (4.54)^2 + \dots}$$

$$= \frac{1 + 133 \times 10^{-5}}{1 + 67 \times 10^{-5}}$$

$$= 1.00133$$

$$= 1.00067$$

That is, the R_{ac} of a carbon electrode 24 in. diameter is only 0.066 per cent higher than the R_{dc} . On this account there would be practically no tendency for the alternating current to concentrate at the surface of the carbon and the use of a hollow cylindrical carbon in place of a solid one becomes unnecessary.

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The annual trip of inspection of the senior class of the Colorado School of Mines will start from Denver on April 20 and last four weeks. The principal mining and metallurgical centers of Colorado, Utah and Montana will be visited.

The Electric Iron Ore Smelting at Hardanger in Norway—II.

BY JOH. HÄRDÉN

In an article* in the February issue, page 82, I gave an account of the first part of Mr. G. Oedqvist's paper, read before the Polytechnic Society of Christiania.

In the following, the second part of Mr. Oedqvist's paper, published in *Teknisk Tidskrift*, Jan. 28, 1914, will be reviewed.

The Quality of the Pig Iron

The results at Hardanger have shown that it was quite possible to produce a good quality of pig iron, free from obnoxious impurities, although coke was used as reducing agent. But the uniformity of the product was far from satisfactory.

The principal reason of the considerable variations in the product is to be found in the undesirable fluctuations of the power consumed by the furnace, with which the author deals further on, and which caused great variation of the temperature in the smelting zone. The real reason of the poor uniformity of the product is therefore, according to Mr. Oedqvist, to be found in the furnace itself.

These variations will be even more prominent when coke is used solely, instead of charcoal.

However, such great variations as those at Hardanger need not always occur, as is evident from the results during the last period when a considerable improvement was obtained. It is clear that the faulty electrical arrangement has had a great influence in this respect as well as with respect to the large percentage of scrap produced.

Stoppages and Interruptions

Table VI shows the stoppages at Hardanger, compared with Uddeholm and Strömsnäs.

TABLE VI

	Stoppages in Per Cent	Interruptions per 24 Hours in Average, Hours
Hardanger, Period I	About 20.8	About 5
Hardanger, Period II	8.5	2
Hardanger, Period III	3.0	1
Hardanger, Period IV	14.0	3 1-3
Uddeholm, Furnace No. 1, March 15 to December 31, 1912	4.0	1
Uddeholm, Furnace No. 2, August 4 to December 31, 1912	4.2	1
Strömsnäs, October 1 to December 31, 1912	2.2	1

Standstills at Trollhättan during the period from Aug. 4, 1911, to Sept. 30, 1912, amounted to about 5.5 per cent. One of these stoppages not due to the working of the furnace or directly caused thereby amounted to 4.7 per cent, while only 0.8 per cent interruptions were directly due to the furnace, corresponding to about ten minutes for each day of twenty-four hours.

The individual causes for the stoppages at Hardanger are not stated in the reports issued, but it appears most likely that the numerous interruptions were mostly caused by breakage of electrodes. That these interruptions had a decisive effect on the uniformity of the product and the general results is quite certain and need not be further explained.

* In this article there is an error on page 83. Line 13 and the following lines of the first column should read: "Hence it seems very likely that a regulation of from 45 to 75 or 80 volts would have been sufficient, with a booster for raising the voltage to say 90 or 95 volts, to be resorted to in cases of emergency, to break through the charge if this furnace got cool after a tapping."

The Load Factor

Table VII shows the electrical load of the furnace at Hardanger, taken as an average for the two best periods.

TABLE VII

The Hardanger Furnace for the Period	Normal Average Load in K.W.	AVERAGE MINIMUM LOAD		AVERAGE MAXIMUM LOAD	
		In K.W.	Decrease in Per Cent of Average Normal Load	In K.W.	Increase in Per Cent of Average Normal Load
September 7 to September 21, 1912	1736	804	About	2207	About
March 6 to March 29, 1913	2004	756	54	2857	62
					42.5

The table shows that the variations in power consumed by the furnace were very great, and that an overload capacity of at least 42.5 per cent above the average normal load was required.

The author does not state the duration of these variations in detail, although especially the period of the overload is of importance in its bearing upon the size of the power plant.

The paper concludes: These irregularities, which were prevailing at the furnace and which were caused by the variations in resistance to which the descending mass of charge was subjected, prevented largely an economic utilization of the available power supply.

The same disadvantages are also well known from some other furnaces in which electrodes are used. The experiences at Trollhättan show that about 200 kw above the normal load must be provided for.

Practically all furnace plants require such overload facilities, at least to a certain extent, since some variations are almost inevitable at times.

At Hardanger, where coke was used only, the above figure of 200 kw was not sufficient, since at least 850 kw over the normal load was occasionally required, and at times even as much as 1000 kw.

This seems to indicate that the use of coke is a direct reason for these variations, especially when the volume of the charge is large in comparison with the volume of the coke.

The paper quotes an extract in this connection from statements made at Trollhättan, from "The Jernkontorets Annaler," 1912, page 319:

"Now it is to be noted that the resistance of the charge in the smelting zone varies for one and the same kind of charge, according to the depth of the iron bath, and in addition, considerably for various kinds of charges. A rich charge, with a small addition of lime only, will cause a rise of the current, and this increase in current consumption will be greater as the 'charge setting' is less, or, in other words, the greater the proportion is between the volumes of the charcoal and the ore charges. A less rich charge again (which also frequently calls for a higher percentage of lime) is acting in the opposite direction, so that a higher voltage is required to obtain the same current density as in the first case."

"We have had sufficient experience in this respect and if the last-mentioned conditions were prevalent, the voltage of 90 volts, which was our maximum voltage obtainable without reconnecting the transformers, was even not quite sufficient during the first hour after tapping, so that the power decreased several hundred kilowatts."

At Hardanger, where no booster was provided and

the maximum voltage was only 78 instead of 90 volts as at Trollhättan, the discrepancies must have been even greater, since coke was used.

(This seems not quite evident to our mind, since a coke charge as a rule has a lower resistance than a charcoal charge, although the volume of the coke is less than that of the latter; an increase of the voltage would have heated up the current path in a comparatively short time, to permit a subsequent decrease to the normal.)

The paper continues: As the low voltage range could not be altered without considerable cost, it seems that the best remedy would have been to work with a richer charge. Instead of this, however, the works at Hardanger chose the opposite way. They abandoned the richer charges and commenced to use Persberg ore with 53 per cent Fe and a charge, giving only about 42 per cent yield.

The result was that the variations in load became greater during this period, compared with the foregoing one, when the charge was richer.

Production

The output of pig iron per year is, of course, of the greatest importance, as far as the economic result generally goes. Table VIII gives a fair idea of the output

TABLE VIII

Plant	Per Cent Pig Iron of Goods	PRODUCTION		A v e r a g e e l o a d i n k i l o w t h u r s	H.P. Available for the Furnaces	TONS PIG IRON			YEARLY PRODUCTION IN TONS	
		Tons per 24 Hours	Tons per 24 Hours Actual Work			Calculated	At 365 Work Days	At 335 Work Days	Calculated	Real ¹
Hardanger, Period I	38.1	5.95	7.51	1665	3500	1.28	0.62	0.57	2743	2172
Hardanger, Period II	50.7	9.6	10.55	1734	3500	1.58	1.0	0.92	3850	3505
Hardanger, Period III	56.4	12.11	12.48	1703	3500	2.01	1.26	1.16	4555	4419
Hardanger, Period IV	41.05	10.48	12.16	1942	3500	1.87	1.09	1.0	4447	3827
Trollhättan, Aug. 4, 1911 to March 6, 1912	56.84	14.92	15.98	1482	2850	2.9	1.56	1.43	5834	5445
Trollhättan, Aug. 12, 1911, to September 30, 1912	63.77	19.53	19.72	1653	2850	3.2	2.5	2.3	7213	7128
Uddeholm, No. 1	53.5	16.82	17.52	1940	3235	2.45	1.9	1.74	6395	6141
Uddeholm, No. 2	52.9	19.31	20.15	1998	3235	2.7	2.18	2.0	7355	7046
Strömsnäs	61.78	20.72	21.2	1833	2850	3.1	2.65	2.45	7736	7561

compared with the results from Trollhättan, Uddeholm and Strömsnäs.

The column "Tons of pig iron per calculated hp-year" refers to the amount of iron, which would have resulted per hp-year, if the power is taken only as per average load, without any stoppages, for a period of fully twelve months. Tons of iron per actual or real hp-year again means the actual quantity produced in proportion to the amount of power provided for the furnace with a smelting time of 365 and 335 days per year, or 12, respectively eleven months.

The "calculated" yearly production refers to the output which would result during twelve months, without interruptions, and the "real" production indicates the output resulting when stoppages are considered and the smelting period is both twelve and eleven months.

The total production per year at Hardanger was, as the table shows, considerably less than from the other plants, in spite of the fact that the Hardanger plant had the largest electrical equipment.

The causes of such a low production figure is, according to Mr. Oedqvist, that only a small proportion of the power available could be utilized in the furnace, as compared with the other plants, and that this was to a

great extent the direct result of the attempt to use coke as reducing agent. Further, that the charge as a general rule had too low percentage of iron. The insufficient electrical arrangements also largely influenced the results during the three first periods.

The above statement by the author of the paper seem to utterly condemn the use of coke for this industry. While this may be so for the plant in question, it would be, to our mind, premature to claim this as a general rule. Trials have shown that coke can be used with good results, if the conditions otherwise are suited for that material, though charcoal would be the ideal reducer. But as already said, this material is gradually rising in price to such an extent that its use is very limited; hence it seems inevitable that serious steps are called for, to enable the use of the more common coke, even if the power-consumption per ton of iron should be thereby increased.

The Electric Efficiency

The electric energy required for this metallurgical process, as compared with the amount of power provided for the plant, is called "the real electric efficiency" by the author of the paper.

This does not include such power as is required for auxiliary machinery necessary, etc., but such losses as occur in the transformers, the power line, cooling of contacts (holders, etc.), radiation losses, variation in working, etc., are included.

Some of the data, which have a bearing upon this, are lacking, wherefore the following figures are more or less approximate, but as they are of general interest they are reproduced in the paper.

TABLE IX

Plant	The "Real" Electric Efficiency, Per Cent
Hardanger, Period I	About 23
Hardanger, Period II	30
Hardanger, Period III	30
Hardanger, Period IV	41
Uddeholm, Furnace 2, August 4 to December 31, 1912	57
Strömsnäs, October 1 to December 31, 1912	60

The above figures should not be regarded as an absolute statement of the efficiency of the respective furnaces, but show the working efficiency only under the specific conditions prevailing during the periods mentioned.

Cost of Electric Energy Per Ton of Pig Iron

The comparative costs of electric power per ton of pig iron produced, both at Hardanger, Uddeholm and Strömsnäs, are shown in Table X.

TABLE X

	COST OF ELECTRIC POWER	
	Per Calculated Ton of Pig Iron, Shillings	Per Actually Produced Ton of Iron, Shillings
Hardanger, Period I	42.53	58.52
Hardanger, Period II	30.30	36.265
Hardanger, Period III	25.61	28.77
Hardanger, Period IV	26.23	33.21
Uddeholm, Furnace I	16.86	19.13
Uddeholm, Furnace II	14.66	16.66
Strömsnäs	12.28	13.69

The figures for "per calculated ton of iron" refer to the cost per ton as calculated for an output which would have resulted if no stoppages had taken place.

The other column, marked "per actually produced tons of iron," includes all stoppages. The table is drawn up under the assumption that the furnaces could be working fully eleven months per year.

The initial cost of power is taken to be equal for all three plants and assumes to be 33.33 shillings per hp-year.

Luton, England.

Some Notes on Stamp-Mills and Milling

BY WM. H. STORMS

There has already been published a large amount of literature on the stamp-mill, so the subject is by no means a new one, but in the following I wish to call attention to a number of matters connected with stamp-mills and milling that usually receive little consideration from those who write on the subject, probably because these matters, in themselves, are so simple that they seem to deserve no particular mention.

I believe, however, that there are many who will find something herein that will be useful to him if he is called upon to run a stamp-mill.

Something About Mortar-Blocks

There has come to exist a very general belief that the mortar of a quartz-mill must have solid bedrock as a base for the mortar-block, and that without it disaster is sure soon to follow. It is desirable to have a bedrock foundation if it can be easily obtained, but it is by no means imperative that the mortar-block, whether of wood or of concrete, rest upon bedrock.

If the block be of wood and a bedrock foundation is readily accessible, it is good practice to lay a foundation of concrete at least 14 in. thick (18 in. is better), in the bottom of the pit on the bedrock, for the reason that the bedrock surface exposed may be of unequal hardness, and should this prove to be the case, the mortar-block is likely to discover the fact later and a movement begun in the wooden structure which will, in time, cause the mortar to have a rocking motion, which is about as undesirable a thing as could happen.

Such a motion is most undesirable for various reasons. It causes the vibrations of the mortar to be unequally distributed; anchor bolts are likely to break, and other damage result, which might have been avoided had a concrete bed been first properly laid. If a bedrock base is unobtainable at reasonable depth, 16 to 18 ft., at most, then the entire mortar block should be made of concrete, giving the sides and ends such a slope angle as will insure a broad base.

Cut the bottom of the pit as nearly level as possible and then build the form within which the concrete is to be placed.

The concrete should be made of clean rock, sharp, clean sand and the best quality of cement obtainable, for the block is to be subjected to what is, perhaps, the hardest usage that concrete foundations are ever required to withstand. A good concrete mixture consists of four parts of clean firm rock, broken to pass a 2½-in. ring; two parts of sand and one part of dry cement. The concrete should be dumped into the form as fast as mixed and rammed until water stands at the surface. When the concrete block is approaching the desired height it will be well to make the last 5 or 6 in. of a somewhat richer mixture, as this is less likely to crack.

If the mortar-block is to be of wood, have it at least 12 ft. long, and build it up by spiking 2 by 12-in.

planks together up to the desired dimensions, placing the planks parallel with the face or front of the mortar (not parallel with the ends). This will give an opportunity to make repairs to the block, or to renew any anchor bolts that may ever require it. Experience has shown that repairs of this kind are not easily made if the planks of the block be set parallel with the ends of the mortar.

Some engineers advise filling in the pit with concrete around the mortar-block. This will, of course, insure stability, but it also insures against making any repairs to the mortar-block without going to the expense of shooting out the concrete and thus exposing the wooden block.

In my opinion, the best way is to dig the pit at least 30 in. wider, on both front and back, than the space required for the block, which will give the necessary room for workmen when making repairs in future years. The pit need be but little longer than the length of the block itself.

In case a wooden block is to be set on a foundation of concrete 16 or 18 in. in thickness, it is best to first lay about 12 in. of concrete and on this place a mixture of sand and cement—3 parts sand to 1 part cement, which makes a very firm and enduring monolithic base.

Carefully chamfer the base of the wooden mortar-block on all sides, cutting away about 1 in. at the bottom, and gradually sloping it to the edge 4 in. above the bottom. Make a form of light boards (1 in. by 4 in.), battered so that they will be just the size of the chamfered lower edge of the mortar-block.

When the concrete and sand foundation has been laid as above suggested, place the wooden form in the position that is to be occupied by the mortar-block, and wedge it firmly in proper place. Then fill the space outside the frame with a grouting of cement-mortar, bringing it even with the top of the form. Allow this grouting to set, after which the form may be removed, leaving a depression on the top of the concrete block. Cover the bottom of the depression thus made with clean sand to the depth of 1 in., and the foundation will then be ready for the lowering of the mortar-block. This should be done by means of chain-blocks, the mortar-block so suspended that its top is level, and it is very necessary that when the block has reached the bottom of the pit that it enter exactly the depression made for it on the top of the concrete base. Every care must be taken to prevent loose rocks, dirt, or other foreign substance from falling into the pit before the mortar-block is lowered into position.

Some mill builders set up the battery frame before lowering the mortar-block into the pit, and without doubt, this is an excellent way, and dispenses with the necessity of a derrick or gin-pole. They build the mortar-block and finish it on the surface, anchor-bolt pockets, the chamfered edge at the bottom, and they even sometimes surface the top. The block, when completed, is moved into position exactly opposite the pit which is to receive it, the pit having first been covered with planks to prevent anything falling into it. The block is then raised by means of jacks, or otherwise, to an angle of about 45 deg., after which it is pulled into vertical position by means of block and tackle, the base resting upon heavy timbers placed across the pit to hold it. A 12 by 12 timber is then laid on top of the battery-posts and chain-blocks made fast beneath it, to lift the mortar-block clear of the timbers upon which it rests, and to control its descent into the pit when all is in readiness. The line-sills are then drawn up tightly, clamping the mortar-block firmly into exact alignment. The timbers

and planks beneath the suspended block are carefully removed from over the pit, and when sure that nothing has fallen into the pit that would prevent the mortar-block from setting squarely on the base prepared for it, the block is allowed to slide downward, by easing up on the line-sills and operating the chain-blocks. When the block, at last rests on the concrete foundation the task is completed. The space around the block should be solidly filled with sand and water poured in to make the sand settle solidly. If tailings direct from a mill in the vicinity can be sluiced in so much the better.

Battery-Post Construction

In this it is merely desired to call attention to the advantages of the four-post frame for units of 10 stamps, over three-post construction, though the latter are by far the more common. In the three-post frame the bull-wheel is at one end of the camshaft, and no matter in what direction the power is applied by the belt, there is a tendency to lift the camshaft out of the box at the opposite end from the bull-wheel, the bearing nearer the wheel acting as a fulcrum. The effect of this is to cause the cam-shaft to vibrate unnecessarily; to loosen the cam-shaft boxes; break up the babbitt-metal and eventually to twist the cam-shaft in two. True, this latter may never happen, particularly if the shaft be of liberal dimensions, but the tendency is in that direction, nevertheless.

If the 10-stamp battery be constructed with four posts, having the bull-wheel keyed between the two center ones, the pull of the belt is equalized as nearly as it can be and the vibrations of the cam-shaft are reduced to a minimum. I have never heard of a broken cam-shaft in a mill built in this manner. The slight additional disadvantage of removing the cam-shaft for the purpose of replacing cams, or for any other reason, due to the fact that the bull-wheel cannot first be removed, is more than offset, in my opinion, by the advantages that the 4-post construction affords.

Height of Discharge

By height of discharge is meant the difference in level between the top of the die and the bottom edge of the discharge surface of the screen. A high discharge tends to retard the escape of the pulp from the mortar; increases the opportunity for the gold to be taken up by the quicksilver in the mortar because of the delay in the escape of the pulp; and it also promotes sliming, which in some ores is very undesirable.

To prevent the sliming of such ores, and at the same time free the gold so that it may amalgamate, a low discharge may be used with a finer screen. This will cause the ore to be crushed finer, freeing the gold from the rock, thus aiding amalgamation, while at the same time affording opportunity for a rapid discharge of the pulp, lessening the likelihood of sliming, which usually results when the pulp is held in the mortar by the high discharge.

When the best height of discharge for any particular ore has been learned by trial, and it can be learned in no other way, this height of discharge should be maintained as nearly as possible. This may be done by the employment of narrow strips of wood under the chuck-blocks. These are removed, one at a time, as the die wears down. It is usual to make these strips about 1½ in. in thickness.

Screens

There are a great many kinds of screens on the market, some of them most excellent, too, but after all it is difficult to get a screen that is generally better

and cheaper (that is, cheaper for the tonnage crushed through them) than the old-fashioned tinned needle-punched screen. It is a good idea to experiment with a variety of screens, for with certain ores some screens give better results than with others. For instance, a flinty ore that under the stamps breaks into splinters and flaky fragments, will discharge better through a slotted screen, or even one of woven wire, than through a needle-punched screen. Such ores, however, are uncommon.

For granular ores the old-time tin screen is good enough, and records of $\frac{1}{2}$ to $\frac{1}{4}$ cent per ton have been frequently made with them, and if they are properly treated before being tacked to the screen-frame, and then suitably mounted, the life of the screen will be prolonged and usually will be all that could reasonably be asked. The tonnage cost will be found to be quite as low as with any other kind of screen, and lower than with some others. Before placing the tin screen on the frame the sheet should be held over a bright fire, such as can easily be produced in any blacksmith's forge, and heated to redness. This burns off the tin and anneals and toughens the iron. When burning off the tin keep the screen in motion so that the heat will be applied evenly over the entire surface, taking care not to burn the metal as this damages it and its life will thereby be greatly shortened, for it is almost certain to break long before it is much worn.

To make any battery-screen more enduring, place strips of thin sheet-packing about an inch in width between the screen and the wood of the frame and the screens will last much longer, thus saving in the cost of the screen and in the time required to fit them to the screen-frame. Always buy those tin screens having an unperforated edge on both sides. Tin screens are mostly made in Germany and are made in large and small sheets. Mill screens made by cutting up large sheets are unsatisfactory, as at least one side has no selvage, and that side will quickly break after being put into service.

Liners

All mill mortars should be provided with liners, and of late years all well-designed mills are thus equipped. Old mills not thus arranged may be provided with liners of some sort. I have had liners made of $\frac{3}{8}$ -in. steel plate to place in the mortars of a mill that were badly worn on all sides. These plates answered the purpose admirably, as well, in fact, as cast-iron liners would have done. Many old mills are without liners and the mortars are, in consequence, badly worn and daily become worse simply because the mill man does not know that he may remedy the difficulty by the exercise of a little ingenuity in making room for liners.

Mr. W. J. Loring, in Trans. A. I. M. E., Vol. XXVIII, 1898, thus describes the condition at one time in the Utica mills at Angels Camp, California, and the manner in which he overcame the difficulty: "The mortars in the mill were not lined, in fact, were not made for lining. After using them for several years it was found necessary to do something very quickly, as each end was worn, just above the dies, to $\frac{3}{8}$ in. in thickness, which, of course, would not stand a great while. These stamps were set 10 in. between centers, using $8\frac{1}{2}$ -in. shoes, and leaving a space of $1\frac{1}{2}$ in. between each two shoes. The dies, 5 in. in height, up to that time, had a life of 59 days, the life of the chrome-steel shoes then used being 191 days. The average number of stamps running per day for 333 days in 1896 was 57 out of 60, and they crushed 273 tons per day. In order to line these mortars I found

it necessary to reset the stamps, using a guide $9\frac{1}{4}$ in. between centers, and leaving $\frac{3}{4}$ in. between the stamps. In this way $1\frac{1}{2}$ in. was gained at each end of the mortars, allowing room for an end liner, which served as a key to the front and back liners. The back was filled with wood, carefully fitted in place, with the liner outside, saving considerable weight in unnecessary iron. This back lining is 13 in. high and stands at $77\frac{1}{2}$ deg., the foot being $1\frac{1}{2}$ in. from the base of the die, which causes the rock, as it is fed into the mortar, to fall on the die. These dies are made with $8\frac{3}{4}$ -in. face, while the shoes have but $8\frac{1}{2}$ in. This I have found to give better results than when both shoe and die are the same size, for the reason that the stem guides are bound to wear, allowing the stamp to swing. A play of $\frac{1}{8}$ in. in the guide will allow the stamp to swing much more at the shoe, causing the shoe to overhang the die. Now, by having the die cast $\frac{1}{4}$ in. larger than the face of the shoe, we utilize the full crushing surface of the stamp. On the other hand, if the shoe and die have a greater difference in diameter, the one having the larger diameter will cup in wearing, causing a loss in efficiency. After making the above changes the mill ran 320 days; average number of stamps per day 59; average number of tons crushed per day, 296; average life of 5-in. cast-iron dies, 120 days; average life of manganese steel shoes, 296 days."

It will be observed from the above that the life of the dies was doubled, and that of the shoes increased by 50 per cent, and that the tonnage crushed was also materially increased by lining the Utica mortars. It would seem that there is a decided advantage in setting the shoes as close as it is safe to set them without interfering, but in doing this it is very necessary that the guides be in first-class condition, not having too much play, or they will interfere and stamp-heads, and sometimes bosses, will be knocked off. The longer life of shoes and dies may be attributed to the better protection they received by having the ore fall directly on the dies, and the increased capacity to this same cause, and to the narrowing of the mortars by inserting the liners.

Where possible shape and fit liners so they can be inverted when one edge is worn, thus getting the full benefit of the value of the material of the liner, otherwise it must be thrown away when only half worn.

Width of Mortar

For rapid crushing use a narrow mortar. For ore that amalgamates with difficulty use a wide mortar, which discharges more slowly and gives the gold a chance to amalgamate, but do not forget in this matter what was said above under height of discharge and screen mesh. It is not necessary that the back of the mortar be the same distance from the edge of the die, as the distance from the opposite side of the die to the screen. The crushing capacity of a stamp-mill will be found to have reached the maximum with a given screen and height of discharge when the distance from the die to the back liner is about $2\frac{1}{2}$ in., and from the front edge of the die to the screen about $5\frac{1}{2}$ in. The back liner should incline backward at 75 to 77 deg. Under no circumstances overfeed the mortar for this not only clogs up the screen, thus decreasing capacity, but it also endangers the screen, which is likely to be broken.

Stamps and Cams

The higher the drop of the stamp the greater the splash and the more rapid the discharge, but there are limitations to the height of drop when speed of revolution of the cam-shaft, which controls the rapidity of

drop of the stamps, is considered. I have known stamps to drop 110 times a minute, using double-arm cams, but the height of drop was only $4\frac{1}{2}$ in. With single-arm cams a still more rapid drop is attainable without danger of camming, but single-arm cams are seldom if ever seen these days, though they were quite common in the early history of milling in California. I doubt if one can be found in the State at the present time.

In the early days those favoring the single-arm cam claimed for it that by its use it is possible to bring the cam-shaft nearer to the stamp-stem, thus permitting the commencement of the lift of the stamp to begin closer to a point directly over the center of the cam-shaft. I do not quite follow this reasoning, for I can see no reason why a cam-shaft equipped with double-arm cams may not be brought as near the stamp-stem as one having single-arm cams. In 1867 there was a mill at Austin, Nev., known as the Mettacorn mill. It was equipped with single-arm cams. The stamps, weighing 900 lb., dropped 10 in. from 98 to 105 times a minute, and it was officially reported by Dr. R. W. Raymond that it ran at this rate for months and never broke a cam. It was a dry-crushing mill, and was built with unusual care for those early days.

Cam-shafts should be of liberal size—5 to 6 in., according to the weight of the stamps and speed of running. Cam-shaft bearings should be broad—10 to 12 in. Cast-iron covers for shaft boxes are unnecessary, but some mill men tack a piece of canvas to the battery-post in such manner that it will cover the box and keep grit out of it. Some mill foremen do not even babbitt the cam-shaft boxes, preferring smooth iron bearings. If the boxes are not well lined up and are babbitted the babbitt-metal is certain to break up from the concussion of the falling stamps, and the pieces of broken babbitt will usually drop down into the mortar, contaminating the amalgam and interfering with amalgamation.

Temperature of Battery Water

A great deal has been written on this subject, but I think the majority are agreed that a temperature of 50 to 60 deg. F. gives the best results in plate amalgamation. If below 50 the mercury is too cold to do the best work, and if above 60 it is too thin and is likely to form small globules on the outside plates, which accumulating, may run off the plate, and if not caught in a mercury-trap at some point below, is lost. In the summer months, when the battery water may get warmer than 60 deg., it may be reduced in temperature by pumping it up into a cooling tower, where, in falling through the screens the temperature is lowered several degrees by the rapid radiation of the heat.

Amalgamating Plates and Tables

Here is another subject over which there is great divergence of opinion, that is, the grade and manner of arranging the outside amalgamating plates. The differences of opinion are principally over the following: Divided plates vs. single sections; drops in the plates vs. no drops; raw copper plates vs. silver-plated copper plates; fixed plates vs. those that are movable and methods of cleaning up.

I never could see any advantage in divided plates. If the entire stream of pulp from a mortar be diverted from the whole surface of a plate to half that area, the result most likely to follow is the scouring off of amalgam already deposited there with very little deposition of new amalgam during the period of overloaded plate.

They who think divided plates the proper thing will, perhaps, argue that the time saved in dressing the plates amounts to more than the loss of the gold. With this argument I do not agree. In the first place there is the danger of the loss of gold already on the plate, and to this may be added the probability that little amalgamation takes place on the overloaded plate. The mill men are paid by the day and therefore their time would be as valuable doing something else. I think most mills have insufficient plate area and a division of the plates results in making a defect worse, and for this reason divided plates are undesirable. There may be places where they would be an advantage, but I have never seen such a place. Some think that divided plates should be used where the ore is very high grade and plates require to be dressed frequently. I should think that the losses would be greater where rich ore was being milled than where the rock was low grade.

Drops, or steps, in the plates, if not too high, are advantageous, as they have a tendency to keep the quick bright and to break up any small balls of sulfides and amalgam that sometimes form and roll away down the plate and are lost unless caught in a mercury trap or on the concentrators. Drops of $\frac{1}{2}$ in., or at most not more than $\frac{3}{4}$ in., will be found to result in an accumulation of amalgam immediately beneath the drop.

Since this is a well-known fact I have sometimes thought that it might be a good idea to arrange the entire plate area with this fact in mind, constructing the plates of narrow strips of silver-plated copper plate arranged in a series of drops each $\frac{1}{2}$ in. or $\frac{3}{4}$ in. in height. Make the strips 3 in. wide. If this were done it is quite possible the grade could be lessened from $1\frac{3}{4}$ in. per foot, which is about the average grade of mill-plates, to $\frac{1}{2}$ in. per foot.

This arrangement in a table 12 ft. in length would give 48 strips each 3 in. wide, and 47 drops of $\frac{1}{2}$ in. each, a total of $23\frac{1}{2}$ in. in the drops, plus a grade of 6 in., in the 12 ft., making a total fall of $29\frac{1}{2}$ in. This would give the series of plates an angle of about 12 deg. The amount of grade, whether $\frac{1}{2}$ in. per foot, more or less, should be determined by experiment. The series of plates could be arranged in sections, say 18 in. each, and so constructed that they could be removed from a frame in which they rest and taken to the clean-up trough for the removal of the amalgam.

There are many who will at once condemn this idea, if for no other reason, because it is something new and untried, but it seems only rational to think that if drops in mill-plates at intervals of 2 to 4 feet are advantageous (and it is well known that they are, as amalgam collects in greater amount just beneath the drops than on the plane surface of the plates), then multiple drops would collect amalgam at as many places as there are drops, and they would therefore be an advantage.

I recently saw a patented amalgamator of cast-iron circular segments arranged in a series of descending steps, and it is said to be an almost perfect amalgamator. It has no copper plates at all, but quicksilver is placed in the annular depressions which form each step of the device, and it is in these that amalgamation takes place.

In these days there are few who will claim any advantage for raw copper plates over those that have been electroplated with silver though when these latter were somewhat of a novelty there were many mill men who candidly expressed a preference for raw plates, and adhered to that idea for many years. Raw copper, if pure and well annealed, makes an excellent plate after it has been broken in, that is to say has accumulated a good coating of gold-amalgam which the mill man does

not scrape off with a steel chisel each time he cleans up, exposing the copper, and making it hard to again get the plate in good condition.

As to the matter of the grade for mill plates, no arbitrary grade can be prescribed. Each mill man must work out this problem for his particular case at each mine, or with each different ore, for there is a vast difference in ores, and the facility with which they will amalgamate. Some ores require a heavier grade than others for their proper treatment by this method. Well designed plate-tables will be provided with means for changing the grade, either by the use of adjusting screws or by means of wedges. This will permit some latitude in the grade of the plates. The grade most commonly given plates in California mills is from $1\frac{1}{2}$ inch to $1\frac{3}{4}$ inch per foot of the plates, not counting any drops that the plate may have. In a few instances the grade is heavier than this, being sometimes as much as $2\frac{1}{2}$ inches per foot. This is very heavy and may not give the best results. Generally speaking, the proper grade is that which will keep the plate free from accumulations of sulphides, but if too heavy the rushing sands will scour the plate. A series of experiments will soon determine the proper grade for any particular ore.

The last thing: fixed or movable plates, is a matter of less consequence than some of the other things here referred to. Undoubtedly it is an advantage to be able to stand up in front of a mortar when placing shoes, dies or liners, or when removing the sands from the bottom of the mortar, instead of kneeling on a board thrown across the table. The tables can be built with a movable section at their upper ends, next to the mortar. This section, which should extend the full width of the plate-table, need not be more than 30 inches wide in the direction of the flow of the pulp. Its upper end should pass beneath the lip of the mortar, and the lower end extend out over the upper end of the fixed portion of the table, which it is best to have securely fastened to the floor. Such an arrangement as here described greatly lessens the hardship of working in the mortar box for any purpose whatever, and as it expedites work is economical and should be provided. When it is to be moved back out of the way, the men can pick it up and lay it over the stationary table.

As to the use of chisels on mill-plates when cleaning up, I see no objection to the practice if the chisels are handled with good judgment by the mill man, but it is injurious to the plate to dig into it with the sharp corner of one of these chisels made by bending an old rasp into the form of a hoe, or gouging the plate in any manner, as I have frequently seen done, in the effort to secure a little more amalgam. Even one of these chisels, ever so vigorously handled will not scrape gold amalgam from a silver-plated copper plate where there is none to be had, though I have often seen it tried, even sweating with hot blankets and scalding water, to say nothing of the gasoline torch. This latter practice is very bad, as it warps the plate and unfits it for further service, and its employment can only be justified, if ever, in making the last cleanup that it is ever expected to make on those plates. I have noticed, however, that the damage to mill plates is usually done in those mills where amalgam is disgustingly scarce. I have found that there is no instrument more satisfactory for cleaning mill plates than the glazier's putty-knife. It is broad, pliable, and easy to handle and will take up amalgam as well as any other kind of knife or chisel I have ever seen used for this purpose, and it does it, too, without injury to the plates.

When good ore is milled for a long time in any mill, the plates always absorb more or less gold, and in time they become rich with it. This is a subject, too, that

has been frequently discussed. However, I will cite but a single instance that came within the range of my own observation: In a certain mill that had been in operation for 11 years, a new manager came in and as the ore those days was rather low-grade he decided to make a thorough clean-up, something that had never been done at this mill. The result was he recovered about \$5,000 to the battery. Some of the gold came from old screenings, some from an old ditch-line through which tailings had run to waste, but by far the larger part of it was taken from the plates which for the first time were sweated and scraped with chisels. A large quantity of high-grade ore had been milled in this mill prior to this episode in its existence, and the new manager came from a district where it was the custom to gouge for every last cent in sight, each time clean-up day came around. It is needless to say in this connection that replating of the mill plates in that mill was of common occurrence. Also, it probably never again became possible to repeat the operation of the new manager at the mill where he made the big find in stored-up amalgam of which the owners had not the slightest suspicion until their attention was called to it.

The Ore-Bins

There is a curious diversity of opinion as to the relative utility of flat-bottomed bins as compared with those having sloping bottoms. Some compromise by building bins that are partly flat and partly sloping.

A flat-bottomed bin affords storage capacity, but should the supply of ore run low, as soon as the angle at which the ore will run down to the chute doors by gravity is reached, men must be put in the bin to pick and shovel the ore down. When the flat floor is reached, if the bin be of good size, some of the ore must be handled at least twice to get it into the feeder chute.

To me it seems that the best place to keep a reserve of ore is in the mine and not in the mill bins. In a mill of 40 stamps, a bin that will hold 1200 tons of ore just as it is delivered from the cars or drops from the breaker floor, is a large bin—few of them are large enough to do it as ordinarily built. In the average California mill this amount of ore will keep the mill of 40 stamps supplied for not longer than six days, while the amount that will run from a full bin to the chutes by gravity is usually not greater than 700 tons in a bin of this size, leaving 500 tons to be shoveled in the event of the supply from the mine running low.

Flat bins are, perhaps, easier to build, but they require more lumber than bins having a sloping bottom. Rock will run quite freely on a slope of 40 degrees, if not clayey, and will come to a state of rest at 35 or 36 degrees, the angle varying somewhat with the material. If the bin is built with a bottom having a slope angle of 35 degrees a few inches of ore will lie on the bottom and thus protect it from the abrasion of rock falling from above. The small amount of ore lying on a slope of this kind can easily be worked down in case it is needed.

When an ore-bin of any shape is filled the movement of the ore at the front of the bin appears to be vertically downward toward the chute door. The result of this movement of the ore is to wear out the planks of the bin for a considerable distance (3 or 4 feet) immediately above the chute door. This may not be noticed at first, but in time it will be seen that the continued abrasion of these places will eventually cut the plank lining in two. This may be avoided by spiking sheets of steel—old turn-plates from the mine, the sides of worn out cars or skips, or anything else of the kind that will afford protection to the lumber of the bins. This protection costs nothing but the trouble of putting it in and will save considerable expense in relining the bin.

In some mills it is evident that it has been considered the most feasible plan to place the rock-breaker in the mill, on an independent frame of heavy timbers. This idea is all right, though it is better still to put the breaker in a separate building if possible. However, if the breaker is to be placed in the mill, and on a separate foundation, do not make the mistake of carefully tying this breaker-frame to the ore bins, and thus to the rest of the mill to give it solidity, nor for any other reason. I have seen this done and could never understand why any millwright, even a very ordinary one, would ever do such a foolish thing.

Where it is possible to conveniently so arrange it, two breakers in series, one set to break to 3 or 4 inches, the other to $1\frac{1}{2}$ inch or less, are desirable, as it increases the capacity of the stamps. This practice is becoming more common as its advantages are better understood. There are some engineers who contend that it is not economical to crush rock in breakers to a size smaller than $2\frac{1}{2}$ -inch, but it is my opinion that the limitations in that direction should be determined by the character of the rock rather than by a fixed rule.

Some Important Negatives

Here are some of the important things that should not be done:

Don't overfeed the mortar, but so adjust the feeder that it will supply the proper amount of rock, protecting the die and securing the largest capacity under existing conditions.

Don't turn too much water inside the battery, and add none at all on the outside plates.

Don't allow sand to accumulate in ridges and islands on the surface of the plates. If it does so promptly sluice it off, being careful not to use too strong a stream of water. If the sand again accumulates sluice it off again and then investigate the cause of it. It may be that the character of the ore has changed somewhat; that the water supply of the battery has been diminished from some cause, or it may be for some other reason, the cause of which must be discovered if possible. It may be that the grade of the plates will have to be increased a little.

Don't permit dark greenish, or bronze-colored spots to remain on the plates. Should any such appear, they are most likely to be due to the presence of soluble sulphates or free acid in the ore or water, or to the presence of some mineral not heretofore noticed. Grease also causes spots to appear on plates, and so does lead or babbitt-metal in the battery. Antidotes for these spots are: Strong solution of salt (NaCl), solution of potassium-cyanide, sodium amalgam, and not the least, a vigorous scouring of the plates with mercury and a suitable cloth. The proper remedy must often be determined by trial, but the last one above suggested is often worth as much as all the others combined, and is a wonder in securing good results.

Don't imagine the mill will run itself after it has once been adjusted, for it will not. Don't neglect the battery. Keep close watch over the entire line, both stamps and plates, that anything that may be going wrong may be quickly detected and the proper remedy applied.

Don't gouge plates with steel chisels to secure amalgam where none is to be had, it is bad for the plates and sometimes for the mill man.

Don't fix an arbitrary time for dressing plates. Dress them when they require it, and in some mills this is often.

Don't lay all the difficulties of amalgamating onto the ore, or on the machinery. It may be the water used in the battery that is at fault, particularly if the water be from the mine. I have known of a mine being con-

demned because the mill men could not amalgamate the gold, and some time later this same ore was hauled away to a custom mill and gave excellent returns and was found to be free milling to an unusual extent. Inquiry developed the fact that the water used in the former trial was from a mine in which there was a noticeable amount of arsenic.

Don't be afraid to have plenty of plate area. If gold can be taken from the last foot or two of plate the probability is that some gold is escaping the plates altogether, and more plate surface would be advisable.

Don't imagine you know it all. Study the operating conditions of your mill and see if they cannot be improved. In many cases they can be. Be wide awake, take one or more technical papers and keep posted, as the saying is, as to the latest and best practice. Often failure has resulted from lack of knowledge of some simple thing unknown in your own experience or in your district, but which is well known elsewhere.

Berkeley, California.

Blast Furnace Blowing Apparatus

BY J. E. JOHNSON, JR.

The power first applied to blowing furnaces was that of water wheels, but something over a generation ago these passed out of use except at very small plants working under peculiar conditions, on account of the lack of water powers of sufficient capacity to drive furnaces with the increasing volumes of wind desired and increasing pressures which those volumes necessitated. This brought about the introduction of the steam engine for blowing purposes. The number of types of such engines, and the method by which they were applied to blowing purposes was almost unlimited.

About thirty years ago one type became predominant and held the lead for a long term of years. This is known as the long cross-head type, it consists of a vertical steam-cylinder with a vertical air-cylinder immediately over it, both pistons being connected to the same piston rod. The shaft passes immediately underneath the center of the steam cylinder with a fly-wheel at each end just outside the bed-plate which supports the whole. These fly-wheels carry crank pins exactly in line with one another so as to act as one.

The cross-head is fastened to the piston rod midway between the two pistons and extends parallel with the main shaft far enough for the wrist pins on its ends to come in line with the crank pins in the fly-wheels. The housings which support the air cylinder from the bed-plate are cut out in the center so that the cross-head can pass through and carry on each side of the opening the slides which guide the latter and take up the horizontal component of the thrust of the connecting rods.

Modern designs of this type of engine are shown in Figs. 1 and 2. This engine has the advantage of securing a direct transmission of the stresses arising in the work of compression directly from one cylinder to the other, and also of having its pistons move in a vertical line and therefore avoids their dragging on the bottoms of the cylinders with resultant friction and wear, a condition which at one time was considered unavoidable with horizontal engines.

This engine is also compact, it requires only a small foundation and small space in the engine house. It is under the disadvantage of requiring two connecting rods, and of requiring very careful workmanship in securing the absolute correctness of alignment of the two crank pins. It also labors under the disadvantages in regard to supervision to which all vertical engines are subject. The advantages were long sufficient to out-

weigh the disadvantages and this type of engine held an absolutely predominant place for a long term of years, and while changes in the conditions have brought about the development of many other types, these engines, when of modern design and economical type, are not only kept in use but new engines of this type continue to be built in considerable numbers. It is, there-

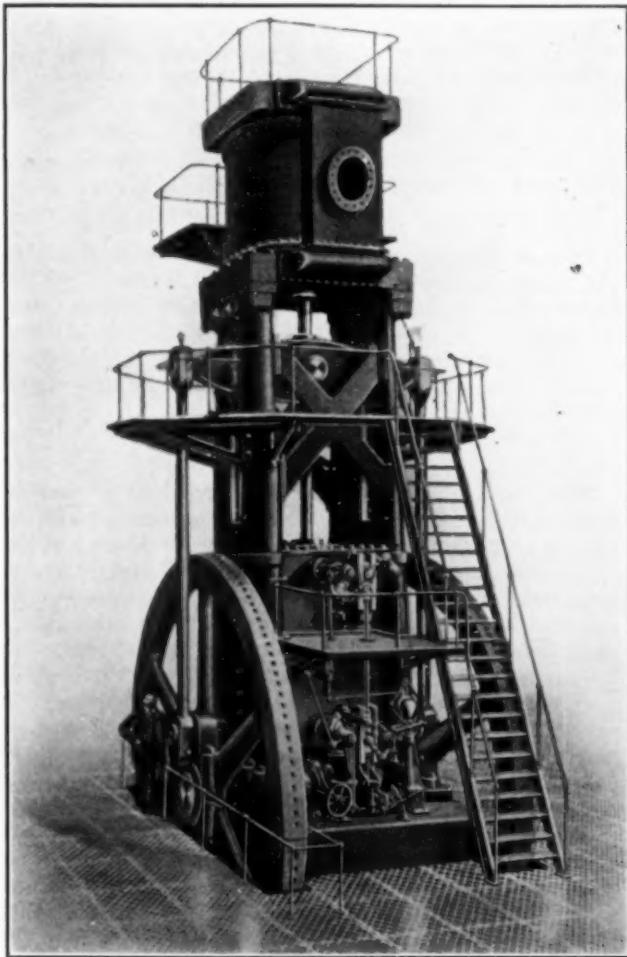


FIG. 1.—SOUTHWARK VERTICAL LONG CROSSHEAD BLOWING ENGINE

fore, with the development of this type that the modern blowing engine has its real beginning.

At the time when these engines obtained their predominance outputs per furnace were small with consequent small requirements for volume of blast and pressures were quite low, probably, on the average, less than one-half of what they are to-day.

As a result the power required per furnace was small and economy as I pointed out in the last article was a factor almost absolutely ignored. The small blast volume required made it possible for few engines of moderate size to supply the blast required for a furnace at a very moderate speed. Hence, there was little or no demand for high speed to cut down the number and size of engines required.

Under these conditions engines were always fitted with some type of self-actuating air valves, in which a slight difference of pressure within and without the cylinder operated both the inlet and the outlet valves in the required direction, and when this difference in pressure was ended and then reversed, as the piston reached the end of its stroke and started on the return, these valves were closed by the return currents of air so set up.

With low pressures and moderate speeds these conditions of operation produced no bad results, especially as the pressure and temperature to which the air was raised by compression were low and therefore valve faces and piston rings could be made of leather and wood respectively, or of other natural fibrous materials. These materials, however, while perfectly satisfactory at low temperature, undergo chemical change with increasing rapidity as the temperature rises and so the time came, as pressure increased, when such materials could no longer satisfactorily be used for these purposes.

This forced the substitution of metal faces for these valves and thus emphasized the two difficulties with automatic valves, the understanding of which had gradually come to pass. First, if these valves are operated entirely by the currents of air which pass through them, they do not seat themselves until these currents are reversed in direction, and then are brought to their seats with a violent shock at any but very low speeds. As long as leather could be used this shock was much cushioned by the leather, but when metal faces became necessary operation under these conditions became increasingly difficult.

Second, the area within these valves on which the excess pressure operates tending to lift them from their seats is less than the area without them tending to hold them closed, by an amount equal to the area of the



FIG. 2.—INSTALLATION OF "MESTA" LONG CROSSHEAD STEAM BLOWING ENGINES

seat itself, which must always be a considerable percentage of the total area. Therefore, the pressure within the valve must always be greater than the pressure without it, in the inverse ratio of the internal and external areas, before the valve will open. This leads to a delayed operation of the valve and necessitates much greater difference between the internal and ex-

ternal pressures than would otherwise be necessary with corresponding loss of power.

If in order to overcome the difficulty of having the valves slammed hard against their seats by the reversed currents, a weight or spring was applied to them to force them to their seats, the pressure due to this weight or spring must be added to the difference between the internal and external pressures, with corresponding further loss of power. It is obvious that as pressures rose and speeds increased these difficulties must be augmented.

There were also other conditions of great importance to be met. First, the clearance should be kept small so that as nearly as possible all the air displaced by the piston may be driven out through the discharge valves instead of simply being compressed into the clearance space, and then re-expanding at the beginning of the next stroke, to the exclusion of air which should be taken in from outside.

Second, the area of the valves must obviously bear a definite ratio to the area and speed of the piston so that a valve area which is quite sufficient to permit relatively complete filling and ready discharge of a given cylinder at a low or moderate speed may be quite insufficient for the same cylinder at a higher speed. It must be remembered particularly in this connection that these losses are frictional and, therefore vary as the square of the velocity, so that a cylinder which will fill with two ounces of suction at thirty revolutions will require one-half a pound at sixty, and a pound and one-eighth at ninety.

To meet as well as possible these conditions of low clearance and large area, a great multiplicity of valves, both for inlet and discharge were adopted, and this was standard practice for many years, there being more than a hundred such valves in each end of an air cylinder of moderate size, in some designs.

With increasing rate of driving came increasing pressure, and this brought about another difficult condition. It modified the shape of the indicator diagram for the air cylinder very much for the worse, from the point of view of the engine. With a blast pressure of four pounds the piston travels only about 20 per cent. of its stroke before the air is compressed to the required pressure and begins to flow through the discharge valves so that with reasonably good design of valves, the work done upon the air cylinder was quite uniformly distributed throughout the stroke and subject to a minimum of variation. With a blast pressure of twenty pounds the piston travels more than 50 per cent. of its stroke against a pressure which rises constantly more rapidly, with the result that about three-fourths of all the work of the stroke is done in its last half.

On the other hand, the older types of uneconomical steam cylinders used but little expansion and so the steam pressure was but little lower at the end of the stroke than it was at the beginning, and the drop which took place was quite gradual with no sharp or sudden changes.

The demand for increased economy grew, as has been pointed out in the last article, and this could only be obtained by one means, much greater completeness of expansion of the steam. This means that under ordinary conditions nearly one-half of the total work of the stroke must be developed in its first quarter, exactly the opposite to the way in which it is consumed, the greatest portion, as we have just seen, being expended in the latter portion of the stroke.

Some form of equalizer has to store the surplus work done in the steam cylinder in the early portion of the stroke, and give it out in the latter portion, and this equalizer is the inertia of the fly-wheel and of the

reciprocating parts, but it is obvious that in a running machine which must have a certain amount of play in its moving parts a complete reversal of the stress from one direction to the opposite, somewhere near the middle of the stroke, could not contribute to its smooth and easy working.

It will be seen from the above that the conditions under which the blowing engine worked in the early days of the long cross-head type grew steadily worse with the development of modern furnace practice. As a consequence of these conditions it is probably safe to say that, next to the furnace itself, blowing engines have given more trouble and furnished more difficult problems to furnace builders and operators than any other portion of the equipment.

Air Valves

To meet the increasing difficulties to which changing conditions subjected the automatic types of valves many designs of positively actuated valves were brought out, of which the test of time has left but few, and it is not possible in a single chapter to treat any except those which have had some considerable degree of industrial success.

CORLISS VALVES

The Corliss or semi-rotating valve had proved its serviceability, its relative ease of operation, and its tightness under long continued wear, by almost half a century of successful use in the steam engine, at the time when the development here under discussion began, therefore it is not surprising that this valve should have been one of the first applied to air cylinders. In its earlier form it was applied in almost the identical way that it was in the steam engine, except that the inlet valve in the air cylinder corresponds to the exhaust valve in the steam cylinder, as does the discharge valve of the air cylinder with the inlet valve of the steam cylinder.

A glance at the indicator diagrams, Figs. 3 and 5, showing steam cards, Figs. 4 and 6 showing air cards, will show that these are of the same general type and shape but one is traced in one direction and the other in the opposite. One represents positive work and the other represents negative work, or energy absorbed. So the base line of one represents spent fluid discharged, and of the other incoming fluid to be compressed.

The inlet line of the air cylinder changes but little with changing conditions, that is to say, the times at which the inlet valve opens and closes are only slightly altered by changes in speed or pressure.

Theoretically the proper time of opening is changed slightly because the greater quantity of air in the clearance space at higher pressures expands to a greater volume at atmospheric pressure, and in order to recover all the energy due to the complete re-expansion of this air the inlet valve should not open until re-expansion brings the pressure of this clearance air down to that of atmosphere, which, of course, means that the inlet valve should open somewhat later with high pressures than with low. But no practical or even appreciable loss is experienced under any ordinary condition, by having this point of opening fixed at the point to suit normal conditions.

For these reasons the inlet valve is positively connected to the eccentric and opens and closes at predetermined points in the stroke. The discharge valve on the other hand ought obviously to open at a different point with four pound pressure from what it would for twenty, and it was long thought that it was necessary to put the opening of this valve under the control of some type of trip mechanism, akin in prin-

ciple to the Corliss dash-pot, which was released by a small auxiliary cylinder in direct communication with the end of the main cylinder, so that as the pressure in the latter rose, the auxiliary piston tripped the releasing gear and the dash-pot pulled the valve open.

It was left for Mr. B. V. Nordberg, of the Nordberg Manufacturing Company, to point out that the loss by having the discharge open a trifle too soon was almost insignificant, in fact practically inappreciable even with very considerable changes in the discharge pressure, and he therefore builds blowing engines, in which both the inlet and the discharge valves are rigidly connected to eccentrics, timed to open and close them at the proper point for normal conditions. A clause in the contract for the first of these engines provided that if it should be found necessary, an automatic gear

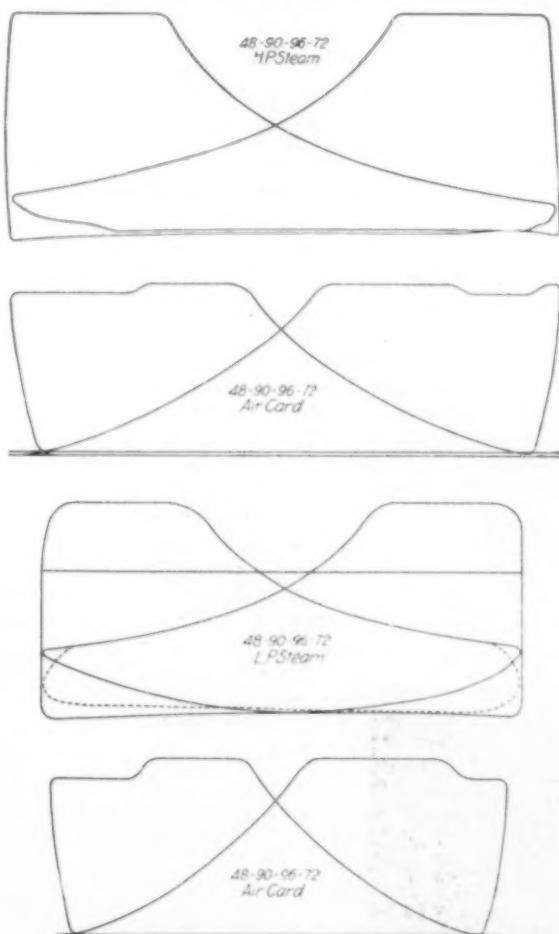
maintained. They also permit large port areas with minimum clearance.

On the other hand they require a considerable quantity of oil for proper lubrication, and one large set of engines with this type of valves so designed as to require an excessive amount of oil to keep them in operation was probably more responsible than any other one condition for their failure to develop into a leading type of valve. In spite of this fact at least one engine with valves of this type is known to the writer which has been in virtually continual operation for twenty-five years and is in first-class condition now.

POT VALVES

The poppet type of valve had always been used for discharge valves and one of the first steps in replacing the Corliss valve for air cylinders was the introduction of a modified form of poppet valve which opens automatically, but is positively closed, an idea first brought out by the German engineer, Riedler.

This valve consists of a hollow steel pot drawn from a single piece of steel. This pot is from eighteen to twenty-four inches in diameter and of approximately the same depth, with a spherical bottom surface, the metal in it is about a quarter of an inch thick in the bottom, and three-sixteenths of an inch in the sides. This closes against a suitable seat in the cylinder head



FIGS. 3 TO 6.—STEAM AND AIR CARDS

would be provided at small additional expense which would shift the point of opening of the discharge valves as the pressure rose, but the results from the engine in practice were almost absolutely perfect, and no conditions ever arose to cause regret at the omission of this automatic device.

Corliss valves have several great advantages. By a suitable design of valve gear they can be made to perform most of their travel at a time when the pressure on their opposite sides is approximately the same, so that they can be moved with a minimum of power and of wear, and owing to the "dead travel" obtainable with a proper design of wrist plate are almost stationary when the unbalanced pressure upon them is considerable. They are held against their seats by pressure, and follow them down as they wear, with the result that their tightness in service under good conditions is well

close to the piston. Inside of it works a plunger, sometimes this plunger is the same diameter as the inside of the pot in which it acts as a piston, sometimes the plunger is of smaller diameter.

This plunger is operated by a rock shaft driven from an eccentric so timed that the plunger forces the valve to its seat an instant before the crank passes the center and before any return current of air can be set up from the receiver back into the cylinder. The plunger is then withdrawn and the valve is held to its seat by the excess pressure within it, since it is provided with small holes around its circumference, just above the seat, which put it into constant communication with the air receiver, and which permit the escape of the air between the plunger and the cylinder, thus helping to bring it to its seat gently and without shock or jar.

One of these valves is shown in the upper portion of the right-hand end of Fig. 7. This type of valve has remained the predominant one throughout the period of supremacy of positively operated valves. The original form of this design was the invention of the late Edwin Reynolds.

Various types of air inlet valves were tried, all designed to keep the clearance down to a minimum and yet give ample area for the admission of air, not only to keep down the suction but to secure the complete filling of the cylinder before the beginning of the compression stroke.

Two of these designs were radical and interesting by their boldness. One was known from its inventor, Mr.

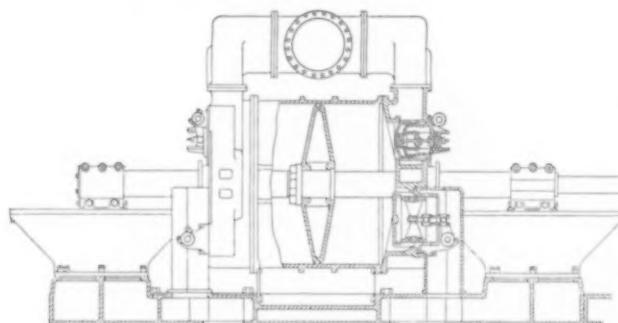


FIG. 7.—REYNOLDS' POPPET VALVE

Julian Kennedy, as the Kennedy inlet valve. It consists, as is shown in Fig. 8, of a long slender cylinder passing entirely through both cylinder heads and the piston of the air cylinder, with suitable packing rings or glands in all three. This cylinder has near its upper and lower ends a system of ports cut through its walls on long spirals, one set for each end of the air cylinder. This valve is driven by an eccentric so that the ports in it are brought within the cylinder head during the admission stroke. Both ends of the valve are perfectly open to the air which passes in through its ends and out through these ports into the cylinder. The valve was properly timed to open and close correctly at each end of the cylinder.

Fig. 8 shows a design in which this valve is set on one side of the cylinder and presumably in this case there are two of these valves. In the ordinary design there was one valve in the center of the cylinder, and the air piston was driven was driven through two piston rods symmetrically spaced on each side of it, a design which has some merit.

The other design was the invention of Mr. E. E. Slick, formerly chief engineer of the Edgar Thompson Works, now general manager of the Cambria Steel

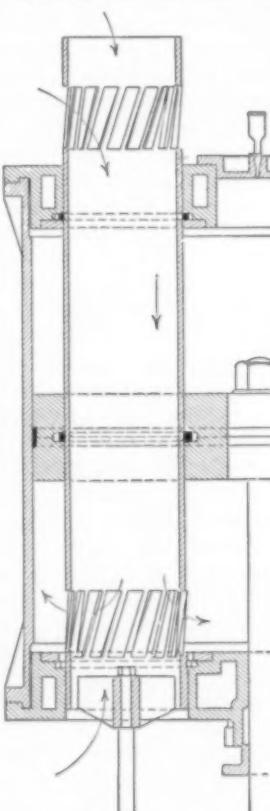


FIG. 8.—KENNEDY INLET VALVE

was moved back and forth by a heavy rock shaft so that during each suction stroke these ports came within the inner surface of the corresponding cylinder head, these being rigidly held independently of the cylinder and making a sliding joint with it like the piston. This obviously gave the whole circumference of the cylinder for a port and yet the clearance due to inlet ports was absolutely nil. This arrangement is shown in Fig. 9, it has been successfully used for a number of years on large and particularly on high-speed blowing engines,

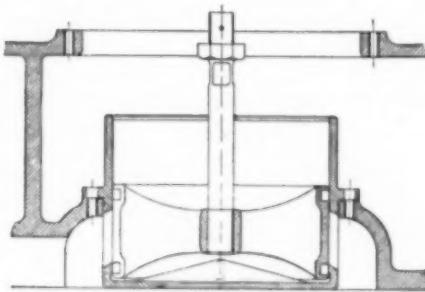


FIG. 10.—KENNEDY PISTON INLET VALVE

but many engineers and furnace operators objected to the awkwardness of the principle involved in sliding cylinder weighing several thousand pounds back and forth through a travel approximating a foot at a rate of sixty, seventy-five, or more revolutions per minute.

The Kennedy valve also was disliked by many engineers and operators because of the great mass of metal to be pulled back and forth through a travel of nearly two feet, and at speeds up to fifty or sixty revolutions, also to the three moving joints necessary in that device, one in the piston, and one in each cylinder head. On several occasions these valves became detached from their driving mechanism and owing to their inertia, due to their weight and high speed, they generally made a wreck of serious proportions under such conditions.

A modification of this valve has been very successful. This is shown in the lower half of the right-hand air cylinder head in Fig. 7 and by Fig. 10. It consists practically of one end of the Kennedy inlet working in a short cylinder set in the main cylinder-head.

The air passes in this case longitudinally through the valve and then outward through the ports in the sleeve which carries it, and so into the main cylinder. The only disadvantage under which this valve suffers as compared with the Kennedy is the slight increase in clearance necessary to carry the air from the ports in the sleeve into the cylinder proper.

The weight of the valve is only a small fraction of that of the Kennedy, and its travel is also much less, so that the inertia of this type of valve is almost insignificant in comparison with the inertia of the Kennedy valve and Slick valve types.

The construction is shown in the illustration.

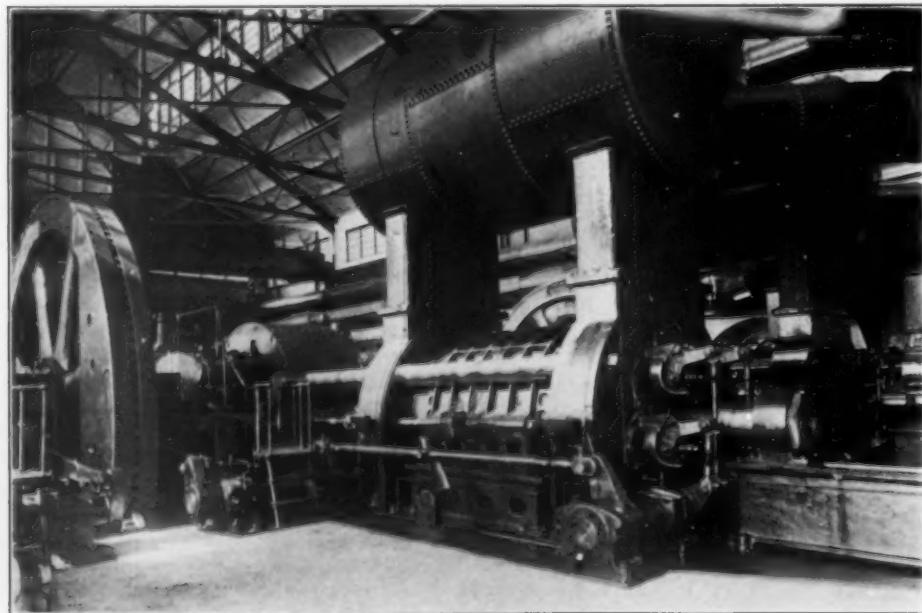


FIG. 9.—SLICK-BLOWING TUBS IN THE CENTRAL FURNACES OF THE AMERICAN STEEL & WIRE CO., CLEVELAND, OHIO

Company. This was still more radical. The whole cylinder was perforated at each end with a set of ports like those in the Kennedy inlet valve, and this cylinder

cant in comparison with the inertia of the Kennedy valve and Slick valve types.

THE SOUTHWARK AIR VALVE

The Southwark Foundry & Machine Company had enjoyed for many years the reputation of pioneer builders of high-speed engines, having developed a system of balanced slide valves for the steam cylinder which could be put under the control of a governor, and permitted these engines to be operated at a higher speed than that attainable by any other type of large

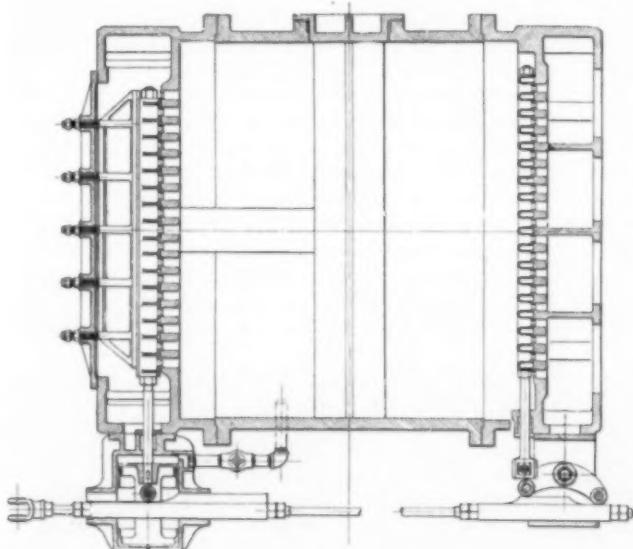


FIG. 11.—SOUTHWARK AIR CYLINDER SHOWING INLET AND OUTLET VALVES, WITH GEAR

engine at the time when the modern development of blowing engines began. They also appreciated the advantages of high speed from a purely mechanical standpoint, notably in regard to inertia stresses and the beneficial effects which they could be made to exercise upon the running of engines. This is a subject which we shall presently discuss.

These two conditions made it natural that the Southwark Company should desire to extend the benefits of their system of high speed engines to blowing engines,

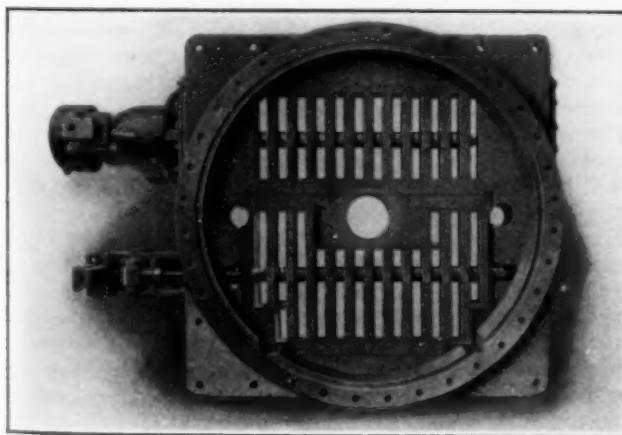


FIG. 12.—SOUTHWARK AIR CYLINDER HEAD, INSIDE VIEW

and they accordingly developed a system of positively operated valves arranged to open and close without shock and to provide ample port area for any speed at which blowing engines could be successfully operated. This system uses a multi-ported or a grid-iron valve both for inlet and outlet. The inlet valve is operated entirely by a cam driven by an eccentric. The inlet valve is on the inside of the head and is unbalanced be-

cause its movements take place only at times when the pressure on both sides of it is the same. The discharge valve is on the outside of the head and is balanced by a cover plate on its back. This valve is closed at the end of the stroke by a cam attached to the same mechanism as that which operates the inlet valve, but is opened by a small auxiliary cylinder in communication with the main cylinder, when the rising pressure in the latter during compression, equals that in the receiver.

A longitudinal section is shown in Fig. 11, and views of a cylinder head with its valves is shown from within and from without by Figs. 12 and 13.

It is probably no more than fair to say that this system of valves was the earliest of any of the mechanically operated valves to be developed into its present condition and at the same time remain in general use. It is also probably fair to say that this valve was the

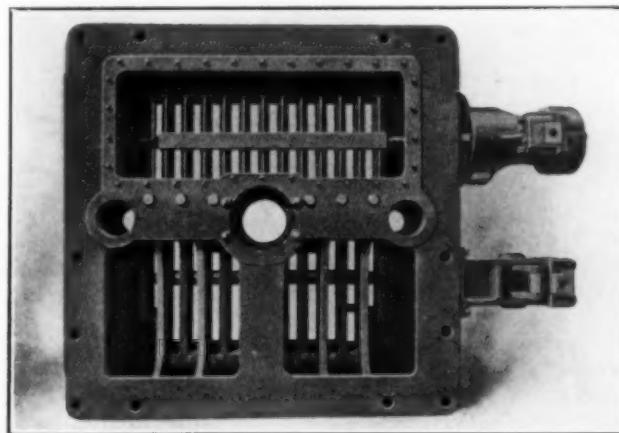


FIG. 13.—SOUTHWARK AIR CYLINDER HEAD, OUTSIDE VIEW

first to be used in this country at the high speeds which are absolutely necessary with gas-driven blowing engines, and which are very desirable with many steam engines.

The Return to Automatic Valves

The last two or three years have seen a development in this field which brings us back almost to the starting point. The gas engine has received a great development in Germany and as the speeds at which it has to run in order to be successful are considerably higher than those customary with steam engines, the question of air valves has been one of great moment to the German engineers, and they have developed a system which modern workmanship and modern metallurgy has made possible.

Each valve consists of three concentric rings held together by radial bars or bridges, the whole being stamped from a single plate of thin special steel. This is fastened to a flat spiral (not helical) steel plate spring held to its seat by a hole through the center.

The valve seat consists of similar but alternately spaced concentric rings, the openings between which constitute the ports and are covered by the valve rings when closed.

The valve is extremely light in weight and requires but a slight lift to give full opening and its inertia is, therefore, very small.

For this reason the small tension of the flat spiral spring is sufficient to seat the valve at the proper time without adding appreciably to the air resistance in passing through it.

The principle of this valve is not essentially different from that of the poppet valve of fifty years ago, but the details of the design are such as to constitute the dif-

ference between failure and success under modern conditions.

The American patent on these valves has been bought by the Mesta Machine Company, of Pittsburgh, by whom they have been redesigned and are being introduced under the name of the Iverson Valve. These are shown in Figs. 14, 15 and 16.

The results with these valves in regard to providing the area necessary for inlet and discharge with minimum suction on the bottom of the indicator card, and minimum excess pressure on its top line, are claimed to be equal, if not superior to, the best of the mechanically operated valves. The clearance is small and the operation of the valves is noiseless.

These valves have one advantage also which I should hardly have believed if I had not seen the results myself. In vertical engines the inertia of the eccentric rods, rock-shafts, and other mechanism for actuating the air valves is sufficient to cause some vibration in almost all engines, and in those of the steeple type this has in many cases been excessive. In cases where these valves have been substituted for mechanically operated valves, the entire absence of any moving parts except these light valves themselves, which only move a distance of an inch or two, eliminates this vibration.

I have seen engines running side by side, one vibrating almost dangerously and the other perfectly still. The manager who was then trying the valves out told me that the engine with the automatic valves had vibrated as violently as the other when it was positively operated.

It is probably too early in this new development to say what its ultimate results will be, but if the promise of the present is fulfilled we shall probably witness the elimination of much complicated and expensive mechanism from our blowing engines in the next few years.

Methods of Compounding

The growth of a demand for economy in blowing engines, previously described, obviously required the introduction of compounding, to which at first sight the long cross-head type of engine did not adapt itself well.



FIG. 14.—VALVE PLATE AND SPRING OF “MESTA” (IVERSON PATENT) AUTOMATIC PLATE VALVE

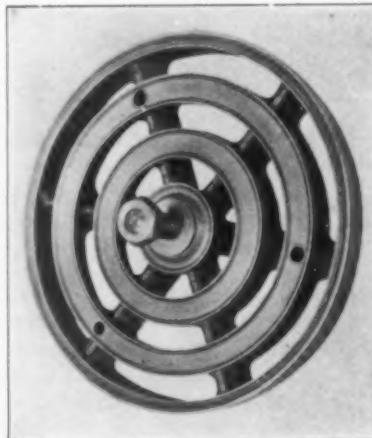


FIG. 15.—VALVE SEAT OF “MESTA” (IVERSON PATENT) AUTOMATIC PLATE VALVE

The late John Fritz solved the problem by putting the high and low pressure cylinder of the compound side by side over the shaft in the position previously occupied by the single cylinder, and connected both piston rods to the long cross head, the position and parallelism of this being rigidly controlled by the connecting rods at its outer ends, by which the continually varying differences in pressures in the two cylinders were absorbed apparently without injurious racking stresses on the engine.

A single air-cylinder was used, as with the simple type of engine, its piston rod being connected to the center of the long cross head as before.

This type of engine, however, never received general favor, and, consequently, other types were developed which adapted themselves to compounding. The principal ones of these types are the horizontal cross-compound with tandem air cylinders, the vertical cross-compound with tandem air cylinders, known as the steeple type, the cross-compound horizontal vertical engine with horizontal steam cylinders working on two cranks at right angles with the air cylinders vertically over these cranks and driven by them, the quarter

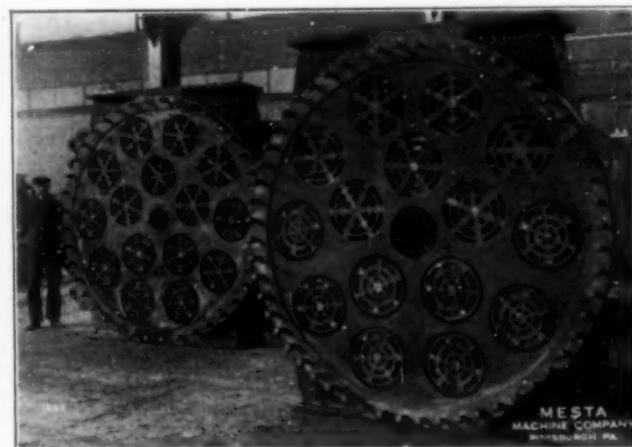


FIG. 16.—AIR HEADS EQUIPPED WITH “MESTA” AUTOMATIC PLATE VALVES (IVERSON PATENT)

crank vertical engine with steam and air sides entirely separated except for the crank shaft which connects them, and the disconnected compounds.

Before we can discuss these different types of engines intelligently the subjects of the inertia of the reciprocating parts and engine friction must be briefly treated. The subject, as applied to the steam engine, will be found in any good treatise on that subject, but the steam engine is very different from any type of blowing engine in which the air and steam pistons are connected to the same rod, for the reason that all work generated in the cylinder, in the power engine, has to pass through moving parts, the cross head pin, crank pin and main bearing, into the crank shaft, from which the useful effect is delivered. While in the blowing engine where the steam and air pistons are rigidly connected to the same rods the energy generated in the steam cylinder is transmitted only through a rigid member directly into the air cylinder, except as has been pointed out that most of the work is generated in the steam cylinder in the early part of its stroke, and the principal utilization in the air cylinders occurs in the latter part of the stroke.

It is obvious that the excess not immediately utilized in the air cylinder must be stored either in the fly-wheel or in the reciprocating parts and given out again to make good the deficiency in the latter part of the stroke. The transmission of these excesses and de-

ficiencies through running parts affects seriously the friction of the engine, which is important not only on account of the power so lost, but because the power lost represents destructive energy applied to the moving parts of the engine itself, and for economy of maintenance if not for economy of power, should be kept as low as possible.

It is probably true to say that the friction of a well built reciprocating steam engine is about 10 per cent. of its indicated horse-power at its rated load, and when running idle, but up to speed, the friction is about one-half of this, that is, about 5 per cent of its rated power.

It is obvious, therefore, that if we can take part of the energy developed in the steam cylinder and apply it directly without its having to pass through the running parts to the fly-wheel, we shall make a considerable saving in friction, and, consequently, in wear.

INERTIA OF RECIPROCATING PARTS

This is not the place for an extended discussion of the subject of the inertia of the reciprocating parts, which is a mathematical problem of no mean order if it be handled completely and accurately. For our purpose, it is sufficient to say that the inertia of the reciprocating parts at the end of their stroke exerts a force equal to the centrifugal force of an equal weight hung on the crank pin, and in the same direction, that is, outward from center of the crank shaft. Starting at this value this inertia diminishes in the same proportion as the distance of the piston from the center of its stroke, at which point the inertia becomes zero. Then, as the piston approaches the other end of the stroke the inertia effect rises from zero to an equal amount in the opposite direction.

It is obvious that this inertia always acts outwardly from the crank shaft; that is to say, at the head end of the stroke it acts toward the head of the cylinder, and at the crank end of the stroke it acts toward the crank end of the cylinder. The fact that this force increases from zero at the center to a maximum at the ends, and then decreases down to the center again on a straight line diagram, should be emphasized, because it is often supposed by those who have not studied the subject that this force is exerted only at the end of the stroke. Nothing could be further from the fact.

The statement of the exact proportionality of this force to the distance from the center of the stroke is exactly true only when the connecting rod is of infinite length, or when the slotted cross head or Scotch yoke is used, which, of course, is never done with blowing engines. With connecting rods of finite length the inertia effect is greater at the head end and less at the crank end than the amount stated, by that fraction of the whole which expresses the ratio of the crank throw to the connecting-rod length. This, while a matter of some importance to designers, is not of sufficient importance for our purpose to necessitate its being taken into account, as the assumption of the straight line diagram for the inertia effect is sufficiently accurate for our purposes.

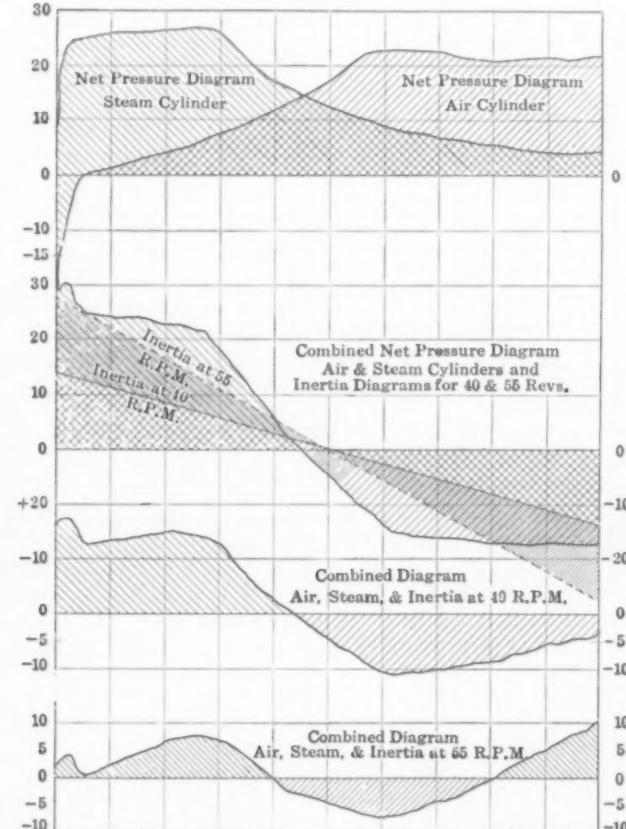
It will be obvious from what has been said that this inertia effect tends to absorb energy from the steam cylinder in the early part of the stroke, when energy is required to accelerate these moving parts, and to give it out again in the latter part of the stroke, when these parts are being retarded by the movement of the crank. This means that the reciprocating parts are taking up energy at a time when the steam cylinder has it to spare, and giving it out at a time when the air cylinder needs it.

In order to investigate this effect quantitatively in relation to the air and steam pressures, it is necessary to

determine the total inertia effect and then consider it as distributed over the air piston as if it were a force of so many pounds to the square inch. Similarly, we can reduce the pressure of the steam cylinder in the ratio of its area to that of the air cylinder, and so put all three of these forces on the basis of a common unit, of pounds per square inch of air cylinder area.

Through the kindness of the William Todd Co., of Youngstown, I have obtained sets of indicator cards from the air and steam cylinders of steam blowing engines, and also similar cards from a gas blowing engine. They have also given me the rated speeds of these engines and the weights of the reciprocating parts, as well as the diameter of the various cylinders and the strokes.

These diagrams for a horizontal cross compound blowing engine with forty-eight-inch high-pressure cyl-



FIGS. 17 TO 20—DIAGRAMS

inder, ninety-inch low pressure, ninety-six-inch air cylinders and sixty-inch stroke in common are those shown in Figs. 3, 4, 5 and 6.

These cards were taken to represent approximately simultaneous conditions in all the cylinders. The rated speed of this engine is forty revolutions, the weight of the reciprocating parts on each side is approximately sixty thousand five hundred pounds.

From these I have laid out what may be called the resultant diagrams of all three forces, that in the steam cylinders, that in the air cylinder, and that of the inertia—all reduced to pounds per square inch of air cylinder area, which are shown in Figs. 17, 18, 19, 20.

There are obviously four sets of such resultant diagrams for such an engine, one representing one stroke in each direction and on each side, but as all of these are more or less similar one will be sufficient to show the principle involved.

We first have to convert the diagrams as taken which represent the conditions throughout the cycle of one

revolution in each end of each cylinder and convert them into "net pressure" diagrams for the steam and for the air cylinders by deducting from the pressure in one direction, the *simultaneous* pressure into the opposite end of the cylinder in the opposite direction, this subtraction being made in the algebraic sense. These two net pressure diagrams are shown in Fig. 17, the pressures of the air diagram being in the opposite direction to those of the steam diagram. Ordinates below the line represent pressure in the opposite direction to that represented by ordinates above the line.

We can obviously combine these two diagrams into one by subtracting the ordinates of one from those of the other in the algebraic sense. The result of this operation is shown in Fig. 18, which shows that the pressure is entirely in one direction during one-half of the stroke, and suddenly changes to the other near the middle of the stroke. On this diagram is shown, as a solid straight line passing through the center, the value of the inertia per square inch of air cylinder area, for forty revolutions, and in dotted lines that for fifty-five revolutions.

Remembering that ordinates of the inertia diagram above the zero line on the left-hand side of the diagram mean energy absorbed, and those below the line on the right hand side of the diagram mean energy given out, we can obviously deduct these ordinates from the net pressure ordinates of the combined diagram for air and steam, and the result will be the final net pressure transmitted to the crank pin. The result of this subtraction is shown in Fig. 19 for forty revolutions, while Fig. 20 shows the result which would be obtained on a similar basis if this engine were run at fifty-five revolutions instead of forty.

It will be obvious at a glance that the energy represented by the triangular area of the inertia diagram has been subtracted from the energy imparted to the fly-wheel in one part of the stroke and subtracted from that given out from the fly-wheel in another part of the stroke, the result being that the energy transmitted through the running parts at forty revolutions is only about one-half of that represented by the total work done, and would become an almost insignificant amount at fifty-five revolutions.

It may be thought that these considerations are too theoretical to be of practical importance, but I have seen large blowing engines in poor condition which would make a noise almost like steam hammers when running at a low rate of speed, but which would quiet down when the speed was increased until at a speed as high as the valve gear would stand they would run silently and well. Moreover, the Southwark Company has designed blowing engines on this principle for many years which have run as successfully as those of any other maker, and more successfully than those of some builders, who use much lower speeds, because they are afraid of the higher ones.

The Nordberg Manufacturing Company also has built blowing engines, some of them to the specifications of the writer, which were designed on this principle. They had a relatively short stroke, and ran at a high rotative speed, and so obtained the displacement of a much larger engine at a lower speed. These engines were properly proportioned as to the inertia stresses and ran with the most perfect smoothness and absence of all pounding and noise at high speeds, seventy-five and eighty revolutions, as well as at lower ones. These facts have a most important bearing upon the design of blowing engine to be preferred.

The Disconnected Compound

The problem of compounding blowing engines has been solved in the case of several of the types of engines

above described, by building two separate units, one containing the high-pressure steam cylinder, the other containing the low, these units being connected only by the steam receiver. These engines are thus enabled to run as compounds and enjoy the benefit of that system, and at the same time retain the flexibility due to small units, because each engine can be run separately. The high-pressure engine has two dispositions for its exhaust, one to the receiver and the other direct to the condenser, or atmosphere. Then, if the low-pressure engine is not needed, or needs repairs, it may be shut down and the high-pressure then exhaust-direct. Similarly, the low-pressure unit has a double source of steam supply, one the receiver steam from the high pressure, the other, live steam throttled through a reducing-valve, so that this engine can be run entirely independent of whether the high pressure unit is in operation or not.

This type of compounding has been applied to the horizontal tandem, the quarter crank vertical, to the horizontal tandem, and particularly to the long cross-head types of engines. In fact, for several years the long cross-head type of engine regained at least in part its old preëminence through the introduction of this system.

When this system is used one engine may be used on one furnace and the other on another, if desired. Where three cylinders are required to blow a furnace, as is not infrequently the case, six of these units, constituting three complete compounds, blow two furnaces, one complete unit on each furnace, the high-pressure of the remaining unit on one furnace and the low on the other. The arrangement of the valves is such that if one furnace is to be shut down, or if the blast be taken off for even a short time, the exhaust valves on the high pressure can be operated simultaneously, the receiver exhaust being closed while the direct exhaust is opened; the steam valves on the low pressure can be similarly operated so that either half of the unit may be kept going on its furnace irrespective of what the other unit is required to do. The governor operates on the high-pressure cylinder only and the cut-off of the low pressure unit is regulated by hand to bring its speed the same as that of the high pressure. This adjustment will hold for a considerable variation of pressure without very much variation from the desired speed on the part of the low-pressure unit, when both are in one furnace, and, consequently, blowing against the same pressure, but when the two units are used on different furnaces whose pressures vary in different ways, the conditions are not so simple and more frequent adjustment of the cutoff on the low-pressure unit is required.

The writer designed several years ago a means whereby these engines could be made to run at the same speed irrespective of the conditions under which they operated, but the manufacturers took no interest in introducing the device, and nothing was ever done with it.

Review of Different Types of Engines

We may now review these different types of engines in the light of the general conditions set forth above, and pass on their desirable and undesirable characteristics.

THE VERTICAL QUARTER CRANK ENGINE.

This engine, shown in Fig. 21, is built in practically the same design by several of the best builders, and is not, as far as I know, recommended particularly by any of them. I shall not, therefore, do any injustice to any of these builders when I say that in my judgment this is the poorest type of blowing engine in regular use today. A certain measure of accessibility is obtained by the fact that it has no tandem cylinders, but it requires a considerable amount of space, a much larger founda-

tion than a long cross-head engine of the same capacity, and an equal if not greater height, while its running parts are very inaccessible for handling with a crane.

The principal objection to it, however, is that it has two complete sets of running gear with their high first cost and maintenance, and that all the energy developed

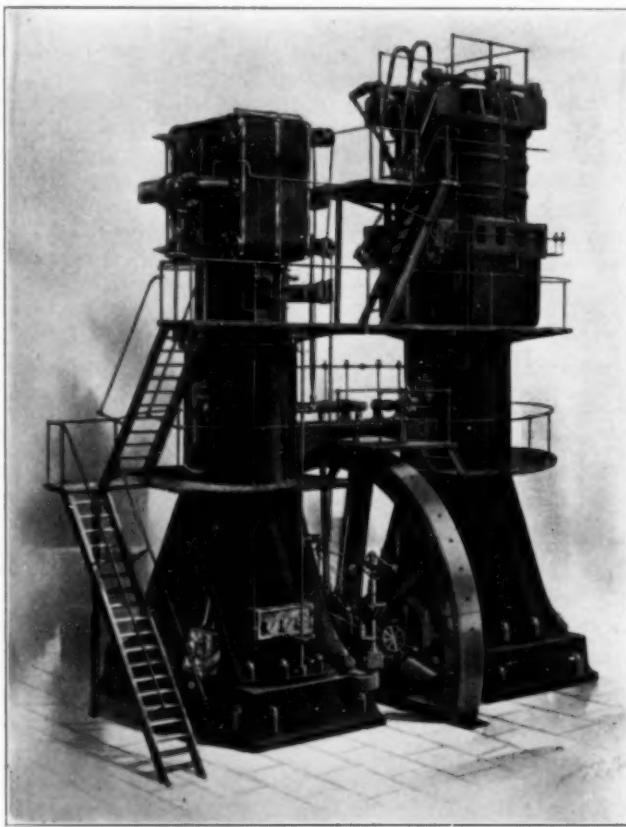


FIG. 21.—VERTICAL QUARTER CRANK BLOWING ENGINE, 42-IN. STEAM, 84 AIR X 60 STROKE

in the steam cylinder has to be transmitted through running parts into the crank-shaft and then from the crank-shaft through another set of running parts into the air cylinder. Taking the mechanical efficiency of a standard steam engine at 90 per cent and the mechanical efficiency of a crank-driven compressor at the same we have an efficiency in this engine of 81 per cent as against 91 to 93 per cent that may be and is secured in regular practice with the tandem connected machine. It is well to remember that this 21 per cent of friction loss as against 8 per cent in the other case, represents not only a loss of power but an expenditure of energy for destructive purposes which must reappear in the form of wear of two sets of heavily stressed running gear instead of one set lightly stressed.

This can, in my judgment, mean in the long run only one thing, high maintenance and repair cost, which, coupled to the high first cost of this type of engine with the consequent high fixed charges, all tend to make this an undesirable type from the technical, operating and financial points of view.

THE HORIZONTAL VERTICAL

The horizontal vertical, shown in Fig. 22, presents almost the same conditions, though these are offset by the fact that the running balance of these engines, if properly made, is excellent, and, therefore, their steadiness on their foundations very great. On the other hand, the horizontal vertical requires as much height

and much greater foundation than the quarter crank vertical.

Many years ago the late P. L. Weimer, realizing that the energy of the steam was mainly developed in the early part of the stroke, and absorbed by the air mainly in the latter part of its stroke, built what are now known as horizontal vertical engines, with horizontal steam cylinders and vertical air cylinders, both working on the same crank pin. With this arrangement the earlier part of the steam stroke obviously takes place during the latter part of the air stroke. Consequently, a certain equalization of the work absorbed and expended from instant to instant is made, which justified in part the use of this type when speeds were low and inertia effects negligible.

In later years these engines have been built by other builders in very large sizes, and are favorably considered by some operators, although the inertia effect with moderate speeds makes this design wholly unnecessary. In these engines, also, it is obvious that the total work generated in the steam cylinder must be transmitted to the crank pin with a friction loss of some 10 per cent, and then transmitted back from the crank pin through another set of running parts to the air cylinder. It is reasonable to assume that here also there is a loss in friction of 10 per cent., making the mechanical efficiency of this engine, also as a whole, only about 81 per cent.

I have unfortunately no figures giving the mechanical efficiency of these engines in service, but there is no reason to expect that it is much higher than the figure given. On the other hand, with the direct connected steam and air pistons of the horizontal tandem and a proper proportioning of the cylinder diameters, speed, etc., it is obvious that only about 20 or 25 per cent. of the total energy need be transmitted through the running parts, and that the friction of the engine accordingly should be only 6 or 7 per cent. instead of 19, as in the other case.

In confirmation of this, which may seem an extreme statement, tests have been made of Nordberg compressors designed to make use of this principle, which had a mechanical efficiency of 95 per cent. at full load.

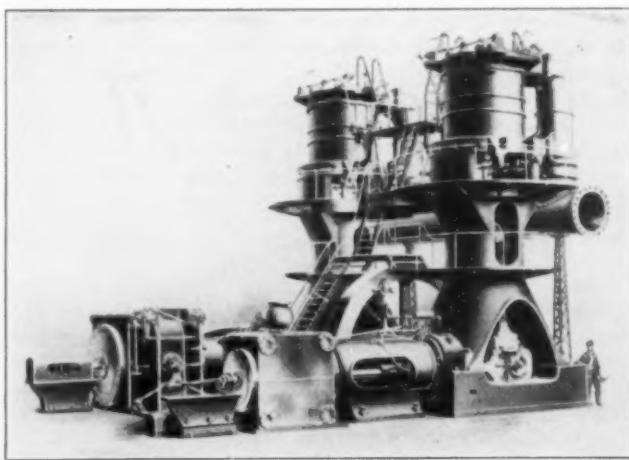


FIG. 22.—HORIZONTAL VERTICAL CROSS-COMPOUND, 52-IN. AND 90-IN. STEAM, 90-IN. AND 90-IN. AIR X 60 STROKE BLOWING ENGINE CO., THE WM. TOD CO.

There is, however, one feature of the horizontal vertical engine which deserves attention. It is evident from what we have said above that the inertia of the reciprocating parts can be utilized to reduce the stresses in the running parts very greatly. Nevertheless the inertia stresses due to these heavy parts which move at high velocities alternately in opposite direc-

tions exist in the machine as a whole and tend to shift it back and forth on its foundation in the case of the horizontal engine without counterweight, or to pull the crank shaft up and down with an equal force if full counterweight be used, these conditions being reversed in the case of the vertical engine. But when two sets of reciprocating parts at right angles work on the same crank, the inertia effect of one set in horizontal and that of the other in vertical, these components are combined into a single constant stress in a direction exactly opposite to that of the crank, so that by counterweighting completely one set of the reciprocating parts, the horizontal-vertical engine runs in almost perfect balance.

Where foundations are bad and engines must be set upon piles driven through mud to the bedrock these considerations are of much importance, and this type of engine is the best adapted of any to prevent serious shaking of the engine and its foundation or even the whole surrounding country for a distance of many hundred feet, as has happened at one large plant where the blowing engines were supported on piles.

THE LONG CROSS-HEAD TYPE

This engine requires small foundation and small space for a unit of given size, the vertical height required being about the same as that of any other type of engine with reciprocating parts in the vertical plane except the vertical tandem, or steeple type, which is much higher. The stresses are, of course, transmitted with great directness in these engines from one piston to the other, and through rigid parts, but there is a prejudice on the part of some engine builders against running these engines at a speed which would bring the inertia effect of their reciprocating parts up to the best point for smooth running and low wear. The exact reason for this disinclination I have never been able to discover, and it is only fair to state that it does not hold with all builders, some of whom build engines of this type to run up to seventy or seventy-five revolutions.

There is no doubt that when run at proper speeds and when built sufficiently strong to withstand vibration, this is a useful, reasonably inexpensive and satisfactory type of engine, capable of giving reliable service for long periods at a stretch, such as are needed in blast-furnace work.

It is, of course, open to the objection which exists with all vertical engines, that supervision, inspection and repairs are much more difficult and expensive than they are with horizontal ones.

THE STEEPLE TYPE OR VERTICAL TANDEM CROSS-COMPOUND

A design of this type of engine built by the Southwark Machine Company is shown in Fig. 23, while nearly all of the prominent builders build this type of engine on demand, the design of valve gear, etc., being different with the different builders, but the general type of construction being the same.

The great objection to this type of engine is its great height with the consequent difficulty of securing adequate inspection and care, and its liability to vibration owing to its height and the elasticity of its small base. It will be seen in the illustration that there are four platforms above the main floor, all of which must be frequently visited for adequate inspection and care of the engine.

It is not to be denied either that these engines are exceedingly difficult of repair. Even where a crane is available, as it should always be in a modern blowing-engine house, there are many parts which it is impos-

sible to reach with the crane without great difficulty, so that this virtually involves partly dismounting the engine for certain repairs. With the limited room available for this work on the platforms it can only be done at a disadvantage, and as a consequence repairs on

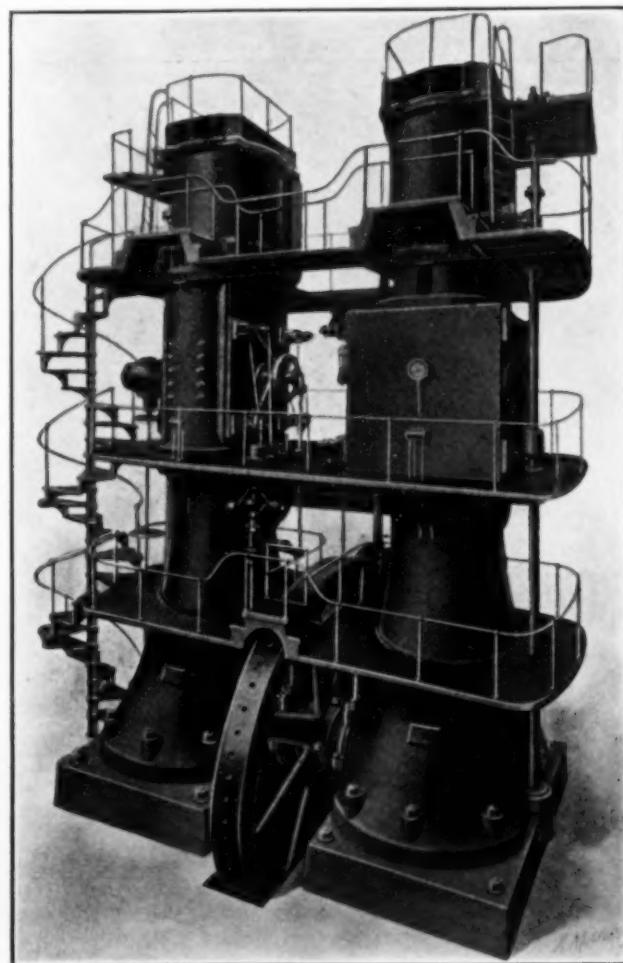


FIG. 23.—SOUTHWARK STEEPLE BLOWING ENGINE QUARTER CRANK COMPOUND

engines of this type are more difficult, slower, and more expensive than they are on a horizontal engine of the same size.

In regard to speed, the engine stands on a relatively small foundation and with its great height excessive

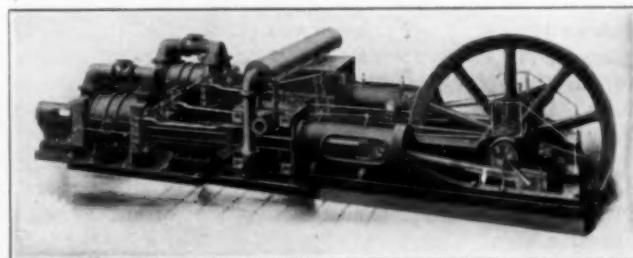


FIG. 24.—HORIZONTAL CROSS-COMPOND BLOWING ENGINE, 44 AND 84 STEAM, 90-IN. AND 90-IN. AIR X 72 STROKE. THE WM. TOD CO., YOUNGSTOWN, OHIO.

vibration is likely to be set up even at very moderate speeds, and this type of engine therefore cannot in general obtain those advantages of high speed which are available to some other types, with consequent loss of

efficiency from not having the most desirable resultant diagram of steam, air, and inertia pressures.

THE HORIZONTAL CROSS-COMPOUND WITH TANDEM AIR CYLINDERS

This type of engine, shown by Figs. 24 and 25, is open to the disadvantage that it requires the largest

Through the kindness of Mr. E. T. Child, of the Southwark Machine Company, I am able to reproduce in Fig. 26 a set of steam and air cards, one of a large number of sets taken by him personally from an engine of this type, running at a proper speed, in which the efficiency for the average of the whole set was about 91 or 92 per cent. This was in actual operation, no par-

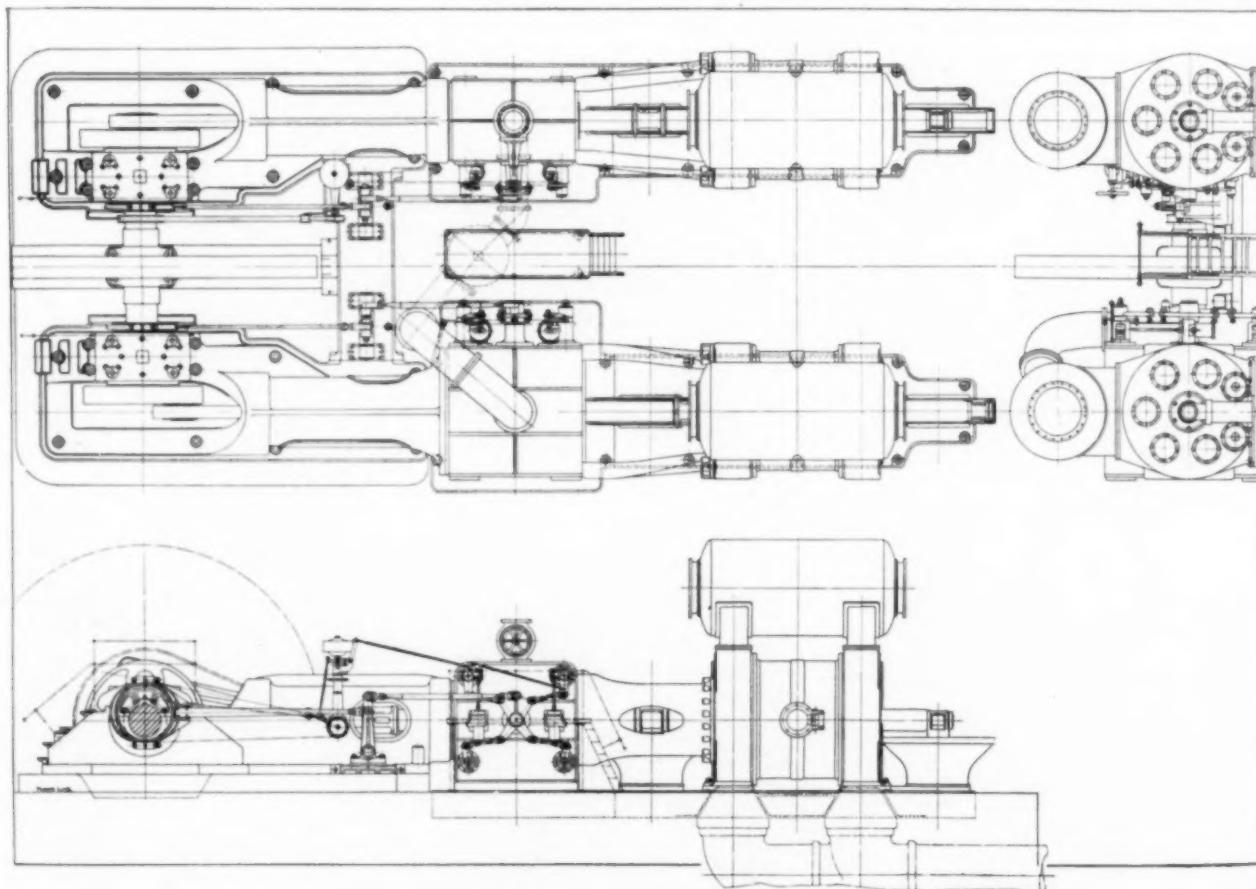


FIG. 25.—“MESTA” CROSS-COMPOUND STEAM BLOWING ENGINE

and most expensive foundation of any steam blowing engine, and that it requires also a great area of building and ground, leading to high cost on this account, but the building cost as a whole is not so excessive as might be expected because of the very moderate height required with this engine, so that only a relatively low building is needed for its accommodation.

Its great foundation also acts as a great anvil to absorb inertia stresses and unbalanced centrifugal effects of counterbalance, which tend to cut down to a minimum the possible vibration of the unit as a whole.

Owing to these considerations the engine is capable of being run at the speed best adapted to produce the highest economy and this higher speed of unit permissible as compared with most other types of engines goes far to offset any disadvantages in total first cost under which a unit of a given size of this type labors as compared with that of some other types. The whole of the engine is down on or near the ground level, and I believe that operators who have had experience will bear me out in saying that one attendant will look after two engines of this type more effectively than two attendants can after one of the steeple type of the same size.

This engine has, of course, the desirable feature of transmitting the stress from one cylinder to another through rigid members and not through moving joints, and in consequence it is capable of realizing the benefits of this system to the maximum.

ticular attempt being made to obtain a record, and I have no doubt that other well-designed engines of this type would do as well, if run at the proper speed.

One of the essential features in the design of the

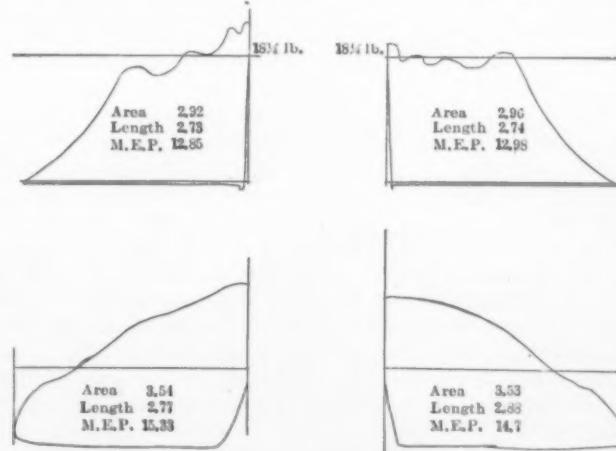


FIG. 26—MECHANICAL EFFICIENCY 92 PER CENT

modern horizontal cross-compounds is the means for relieving the bottom of the cylinders of the drag of the heavy pistons necessary in large units. This is accomplished by putting a cross-head and slide at each end of each of these large cylinders and making the piston

rods strong enough to carry the pistons clear of the cylinder, so that nothing but the packing ring touches the wall of the cylinder.

In some cases the piston rods are made of high-grade steel and cambered upward before use to the amount by which the weight of the piston will deflect them so that they are perfectly straight in service.

Mr. Nordberg has gone still further and uses a hollow cast-iron trunk of large diameter whose only function is to carry the weight of the piston and take compression stresses, the tension stresses all being taken by a much smaller steel rod through the center.

The type shown is built as a cross-compound steam engine and this type of construction is also much used in gas engines. It has many of the advantages of the horizontal tandem engines but the simplicity and accessibility of the running gear due to the stretcher rods from one cross-head to the other are not so great as in the straight tandem type, and I have never known what advantages this engine possessed to offset these disadvantages unless it be the accessibility of the cylinders due to the elimination of the tandem arrangement. It is a type of engine approved by engine builders very generally, and is recommended by them for high speeds.

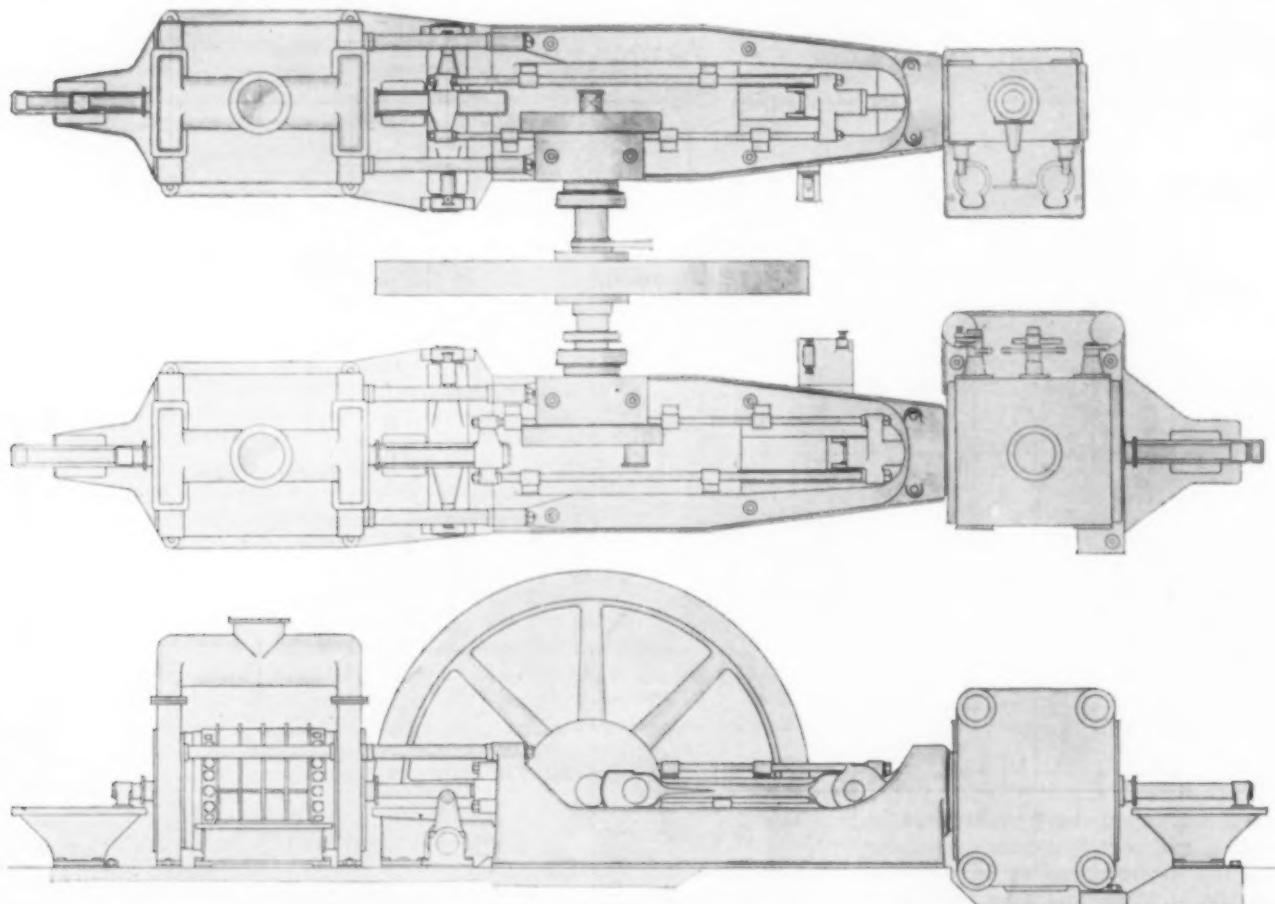


FIG. 27—INSIDE-CRANK BLOWING ENGINE SLICK AIR CYLINDERS 36 IN. AND 72 IN. X 54 IN. STEAM, 72 IN. AND 72 IN. X 54 IN. AIR. ALLIS-CHALMERS COMPANY

This design not only frees the engine from a very heavy friction load, but also relieves the cylinders from wear and puts them on a parity in that respect with vertical cylinders.

THE INSIDE-CRANK ENGINE

The inside-crank type of engine is shown in Fig. 27.

The crankshaft lies between the two cylinders and the piston rod instead of passing directly from one cylinder to the other; is divided into two parallel rods symmetrically placed with reference to the axis of the cylinders, and in a plane about 45 deg. from the horizontal.

These two parallel rods take hold of suitable projections which are provided on the cross-heads for each cylinder.

This arrangement makes an uninterrupted open space in the axis of the engine and between the two cylinders in this uninterrupted open space the connecting rod and crank work.

The Foxboro Company, recently organized under the laws of the Commonwealth of Massachusetts, has taken over all assets and liabilities of The Industrial Instrument Company of Connecticut, which was a holding company, and of The Standard Gauge Manufacturing Company of Connecticut, with factory at Foxboro, Massachusetts. The Foxboro Company manufactures the rapidly growing line of Foxboro improved recording gauges, thermometers, tachometers and pyrometers which are sold by the Industrial Instrument Company having main office at Foxboro, with branch offices at New York, Chicago, St. Louis, San Francisco, and Birmingham. The Foxboro Company owns all of the capital stock of The Industrial Instrument Company. Mr. Edgar H. Bristol and Mr. Bennet B. Bristol continue as president and treasurer respectively of The Foxboro Company. In fact, there are no changes in the personnel or policies of the companies, the above changes being made to concentrate and simplify the organization.

Concentration of Complex Sulphide Ore from the Mary Murphy Mine¹

BY GEORGE E. COLLINS

Nothing can be farther from the truth than the common idea that a scheme of ore-treatment can be finally worked out in all its details prior to construction of a milling plant; or that such a scheme, once fixed, should need no reconsideration during the life of the mine it has to serve. This presupposes a homogeneous ore-deposit, unchanged scale and methods of working, and an amount of time and completeness of facilities for testing which are rarely available in practice.

In actual experience, uniform ore-bodies are uncommon. Perhaps the large low-grade dissemination and replacement ore-bodies approach nearest to uniformity; and even these appear so, largely because they are worked on so great a scale that their mineralogical and physical differences are averaged. And while, in the case of some of these large low-grade mines, great sums were spent in testing and on experimental plants before the serious work of construction was commenced, nothing is more certain than that radical changes are yet possible. It is therefore no reflection on the skill of the metallurgist or the thoroughness of his preliminary work, if he finds it necessary to continue testing throughout the life of the plant.

Constant testing is necessary, not merely to indicate ways in which the metallurgical saving of a plant may be improved, but also to control the working costs, and the relation of metallurgical to commercial saving. Furthermore, when the most suitable practice has been established, it is necessary to repeat similar tests at intervals, so as to ensure that no changed factor has crept into the practice, unknown to the management. Even apart from all these, there is a duty incumbent on every engineer to investigate the reasons for what he is doing and the results achieved by it; and last of all, the possibility that by constant study and record of his own results he may add to the general stock of knowledge, by the aid of which he may assist his fellows in solving similar problems more expeditiously.

Discordant Results Obtained in Testing

I do not know whether engineers experience as much difficulty as I do in obtaining concordant results from their testing work. If so, they do not mention it in their published results. Having had the painful privilege in some cases of "cleaning up" after some of my confrères, I incline to suspect that the difference is sometimes one of puzzling out the discordant results on the one hand, and covering them up on the other.

There are innumerable chances for results to go wrong, either in the preparation of the samples, or in the assay office itself. I suppose that by the exercise of infinite care such discrepancies might be avoided, but so far I have not found any way of discovering or educating infallible men. Both from the point of view of general efficiency of staff and that of effective control of operation, I prefer to get a large amount of work through, and a large number of screen analyses and other tests made, even at the risk of having some inconsistent results included in the reports. Even with this, the tendency is to delay the completion of tests until they have become old history, and have to a large extent lost their value for the guidance of everyday operation.

I suppose everybody has had much the same experi-

ence; but it may be worth while, in order to illustrate the difficulties that crop up in this class of work, to give one example:

TABLE I—SCREEN ANALYSIS

4 Ft. HARDINGE MILL RE-GRINDING JIG MIDDLING
Elevation from feed to discharge end, 11". Speed 30 R.P.M.
Solids = 18.7% = 22.63 tons ore per 24 hours.
Water = 81.3% = 120.00 tons water per 24 hours.
Total tonnage 142.63 tons per 24 hours.

Sample No.	Mesh	% ..	FEED				DISCHARGE						
			Oz. per Ton		Percent-age		Sample No.	Mesh	%	Oz. per Ton		Percent-age	
			Au.	Ag.	Pb.	Zn.				Au.	Ag.	Pb.	Zn.
D-1.....	+ 20	46.34	.60	5.2	17.2	33.6	DD-0.....	+ 20	....	....	....	....	....
2.....	+ 40	12.20	.64	5.7	16.0	32.4	DD-0.....	+ 40	....	....	....	....	....
3.....	+ 60	7.32	.36	4.5	18.7	22.8	1.....	+ 60	2.44	*	*	7.5	23.2
4.....	+120	8.54	.32	4.3	8.2	17.6	2.....	+100	12.19	1.00	9.0	5.7	22.5
5.....	+200	14.63	.26	6.0	9.8	15.0	3.....	+200	34.15	1.24	5.4	11.0	26.5
6.....	-200	10.87	.28	6.0	16.5	12.3	4.....	-201	31.22	.38	6.8	8.8	24.3
Average assay (calculated).....			.48	5.3	15.2	26.2	Average assay (calculated).....			.92	6.6	9.1	24.8

*Not enough for assay.

PERCENTAGES OF TOTAL CONTENTS IN VARIOUS SIZED PRODUCTS

Mesh	Au.	Ag.	Pb.	Zn.	Mesh	Au.	Ag.	Pb.	Zn.
+ 20	58.1	45.1	52.3	59.3	+ 40	....	....	....	....
+ 40	16.3	13.0	12.8	15.1	+ 60	....	....	2.0	2.3
+ 60	5.5	6.2	9.0	6.4	+100	13.6	17.1	7.6	11.1
+100	5.7	6.9	4.6	5.7	+200	47.4	28.7	41.1	36.5
+200	7.9	16.4	9.4	8.4	-200	38.9	54.2	49.3	50.1
-200	6.4	12.3	11.9	5.1					

Here it will be observed that in the process of crushing, according to the screen analyses, the gold has been raised from 0.48 oz. to 0.92 oz. per ton, and the lead has dropped from 15.25 per cent. to 9.14 per cent.

There is nothing exceptional about the former; we have found that gold tends to accumulate in tube-mills, jig-beds, elevator sumps, etc.—in fact, everywhere in the plant where there is any opportunity for extreme classification to take place, and for exceptionally heavy particles to lodge. I shall return to this subject later.

The changes in the lead percentage are less to be expected *a priori*. But it illustrates the fact that the Hardinge mill (or other tube-mill) is a natural classifier, in which the heavier particles are retained longer, and ground finer, than the relatively lighter particles. As in this plant we always run a machine two shifts or more after making any change before taking samples, this should not lead to discordant results, if the feed were uniform. Uniformity of feed, however, is a most difficult thing to secure, when you have a mine yielding excessively variable ores, and a mill of moderate or small capacity. In this case we have a storage, with some natural mixing in the crushed-ore bins, of over five days' mill capacity; or an average of say two and one-half days' ore always on hand; yet uniformity of feed is an ideal which we have never attained.

Any change in grade or fineness, occurring within a couple of hours of the time when a test is being made, takes several hours before the discharge and feed are equalized; and meantime other changes may have occurred. In order to obtain concordant results from feed and discharge, therefore, it is desirable to continue a test for a week or more, samples of feed and discharge being taken at regular intervals throughout. As we cannot always wait so long for results or tie up a machine so long for purely experimental purposes, it is sometimes necessary to put up with results which

¹Excerpt from the author's presidential address before the Colorado Scientific Society, entitled "Systematic Testing in the Evolution of Mill Practice." The portion here given has reference to the Mary Murphy mill, and affords interesting supplementary data to a descriptive article on the same mill, published in our issue for January, 1914, and to Mr. Dyke V. Keedy's discussion of that article in our issue for March, 1914.

we know beforehand may be incorrect, in some direction.

The variations in assay serve as an index to probable corresponding variations in sizing. The sulphide minerals being so much softer than the gangue, it is certain that if there are unequal proportions of mineral in the feed and discharge, there will be corresponding variations in the proportions in the sizing, apart from those normally due to the work performed in the mill.

A similar discrepancy was observed in assays of feed and discharge from a 4-foot Hardinge mill which we used experimentally for regrinding coarse sand tailing, with a view to its treatment on carpets and plates. This operation yielded a small quantity of amalgam, and some carpet washings assaying 2.75 ounces of gold per ton. Yet, during a period of several weeks, the daily samples of heads and tails showed, with I believe only two exceptions, a slightly higher gold content in the latter than in the former. The explanation, in this instance, must be that minute particles of gold and amalgam had lodged in the interstices of the silex lining, and collected in the enriched sands left in the mill before the test commenced, and gradually worked their way out in admixture with the pulp. Had we foreseen this difficulty, we might have avoided it by deferring this test until the mill had been newly lined, and then started it up with a new load of pebbles. We, however, supposed, not unnaturally, that as we intended continuing this test for a considerable period of time, any irregularities of the kind indicated would naturally adjust themselves after running a day or two.

Conical and Cylindrical Tube Mills

It follows from the foregoing, I think, that no crushing appliance in which, as in the Hardinge and ordinary cylindrical tube-mill, classification takes place, can ever be a perfect non-sliming fine grinder.

The conical end of the Hardinge mill acts, to some extent, as a device to expedite continuous discharge, in much the same way as the device recently brought out by Chalmers and Williams for improving the discharge from a cylindrical tube-mill. The latter, which consists of a perforated diaphragm, between which and the discharge end is a series of adjustable shelves intended to raise the pulp to the center where it can flow out, may be more effective, but has not yet been tried out sufficiently to prove its value. The conical end of the Hardinge, while of limited efficiency, is simple and positive, and really works. One can obtain nearly as small a proportion of slime in a long tube-mill as in a Hardinge, by crowding the feed and using a large quantity of water; but apparently there is then a slight tendency for the discharge to contain still more oversize.

Mr. Hardinge's original contention that with his mill the weight of blow is automatically adjusted to suit the progressively finer particles of pulp as they pass from head to discharge end, and that owing to this automatic adjustment there is practically no necessity for return of oversize, is, according to our experience, not borne out by the facts. As in the case of the tube-mill, if you crowd the tonnage and increase the water sufficiently to obtain a granular product you have to arrange for the return of a very considerable amount of oversize.

In various publications Hardinge has illustrated this supposed zonal action in his mill by cuts in which he superimposes on a picture of the conical mill, an outline of several gravity stamps, commencing with one of heavy weight and high drop, and progressively lessening to one of small weight and low drop at the end; the stamps being supposed to represent the force of blow

struck by the pebbles in the corresponding stages of the Hardinge mill as you pass from feed to discharge end.

This is, however, largely a fallacy. It is true that the size of pebbles is automatically graded, to some extent, and obviously the force of blow struck would be thereby lessened. But the peripheral speed is at the same time lessened to such a degree that near the discharge end the pebbles merely slide on one another without cascading, so that there is no crushing action worth mentioning, and what actually occurs is a slight process of abrasion, which is just what we want to avoid. In fact, in comparing the work of the Hardinge with that of the tube-mill, according to our experience, it is pretty much a question of relative first cost and operating expense. We have at Romley one 3½-foot by 16-foot Gates tube-mill, two 6-foot by 22-inch Hardinge mills, and one 4-foot by 22-inch Hardinge. We find that the capacity of the tube-mill and that of one 6-foot Hardinge, using the same feed, are almost identical; and the cost of the Hardinge was about 20 per cent. greater. As to power consumption, we have no means of measuring. The Hardinge uses more pebbles, and has to be relined oftener.

Separate Regrinding of Sand Tailing and Mineralized Middling

In the Mary Murphy mill, we have hitherto used the 6-foot Hardinges and the tube-mill to do the same work on the same feed. As the result of our experiments, we expect hereafter to do the bulk of the regrinding with the Hardinges, using the tube-mill to regrind the coarse sands from the tables. The 4-foot Hardinge was intended, and is still used, to grind the heavily mineralized middling from jigs, the idea being that this material required for proper granulation a lighter pebble and less total weight of pebbles; furthermore, that it should be more satisfactorily ground by itself, unmixed with the particles of hard, tough quartz and rhodonite of the gangue. I now doubt very much if this latter hypothesis was correct; and incline to suspect that one effect of the hard gangue particles may be to protect the soft grains of mineral, in some degree, from sliming after they have once been crushed fine enough. What, however, is certain is that crushing the jig-middling in a separate machine enables us to realize precisely what result we are actually obtaining. This is indicated by the color of the discharge, which looks a good deal like ink, and by the screen analyses, which show anywhere from 30 to 70 per cent. of —200 size, averaging in metallic contents 65 per cent. of the lead and 51 per cent. of the total zinc.

The sizes below 100-mesh contain nearly all the lead and most of the zinc in the feed (93 per cent. of the total lead and 85 per cent. of the total zinc).

As stated above, by greatly crowding the feed we are able to lessen the proportion of unduly ground material, to a very large extent. This is well shown by the screen analysis (Table II) which shows only 12.1 per cent. of —200-mesh material.

The use of this method is, however, not always possible; for in a small plant, or even one of moderate size, the tonnage available of any given material is limited, and is fixed by the relation between various factors due to other machines; and by no means always corresponds with the sizes of machines commercially manufactured. And this again is a decided disadvantage, for small plants, of the entire tube-mill class of machine, in which the character of the product as well as the cost of operation is modified by the quantity of feed.

Moreover, in the example shown, the lessened quantity of undersize is obtained at the expense of produc-

ing a prohibitive proportion of oversize (49.3 per cent.).

To show the enormous influence on product of differing quantities of feed, the character remaining similar, I reproduce screen analysis (Table III) which shows that by reducing the feed to 14 tons, keeping the other factors approximately constant, the result was entire elimination of oversize, but the increase of —200-mesh product to the enormous figure of 72.8 per cent.

TABLE II—SCREEN ANALYSIS

4 FT. HARDINGE MILL.							RE-GRINDING JIG MIDDLING						
Elevation from feed to discharge end 11 $\frac{1}{2}$ ". Speed 28 R.P.M.													
Solids = 32.4% = 34.6 tons per 24 hours.													
Water = 67.6% = 72.0 tons per 24 hours.													
Total tonnage 106.6 tons per 24 hours.													
Pebble Load, 0.9 tons. Main mill treating 140 tons per 24 hours at the time when samples were taken													
FEED							DISCHARGE						
Mesh	%	Au.	Ag.	Pb.	Zn.		Mesh	%	Au.	Ag.	Pb.	Zn.	
On 10	32.6	.12	2.1	6.8	11.0		On 10	3.0	.22	2.9	4.4	9.5	
" 14	17.0	.30	1.9	4.7	11.3		" 14	4.2	.18	2.4	4.4	10.0	
" 20	14.5	.18	2.0	4.1	10.1		" 20	7.2	1.24	2.3	3.8	9.4	
" 35	11.6	.21	2.3	4.1	10.3		" 28	10.2	.56	2.2	3.5	9.2	
" 48	8.3	.14	2.3	4.4	10.7		" 35	12.1	.42	2.1	3.5	9.0	
" 65	3.1	.14	1.9	3.1	11.3		" 48	12.6	.42	2.6	3.8	10.6	
" 100	2.9	.12	1.8	2.5	12.7		" 65	11.1	.44	2.9	6.3	14.1	
" 150	2.4	.09	1.7	1.7	11.7		" 100	10.7	.44	3.2	7.4	15.5	
" 200	1.1	.09	2.0	2.5	11.7		" 150	9.6	.40	2.9	9.6	16.1	
thru200	1.8	.12	3.9	8.9	13.0		" 200	7.2	.21	3.7	13.4	15.1	
Calculated average assay	.15	2.1	5.0	10.9			Calculated average assay	.44	2.9	7.1	12.1		

(Tyler standard testing screens used in above test.)

TABLE III—SCREEN ANALYSIS

4 FT. HARDINGE MILL.							RE-GRINDING JIG MIDDLING						
Elevation from feed to discharge end 11 $\frac{1}{2}$ ". Speed 28 R.P.M.													
Solids = 35% = 14.04 tons per 24 hours.							Mill running two shifts before samples were taken						
Water = 65% = 26.07 tons per 24 hours.													
Total tonnage 40.11 tons per 24 hours.													
Pebble Load, 0.8 tons. Selex lining. Main mill treating 150 tons per 24 hours at the time when samples were taken													
FEED							DISCHARGE						
Mesh	%	Au.	Ag.	Pb.	Zn.		Mesh	%	Au.	Ag.	Pb.	Zn.	
On 10	66.0	.40	6.4	22.0	23.5		On 10	.....	.....	.....	.....	.....
" 14	16.0	.22	7.6	16.2	22.8		" 14	.....	.....	.....	.....	.....
" 20	9.9	.26	5.1	16.2	21.7		" 20	.....	.....	.....	.....	.....
" 28	4.2	.34	5.9	19.0	19.0		" 28	.....	.....	.....	.....	.....
" 35	.....	.....	Not enough for assay	.....	.....		" 35	.....	.....	.....	.....	.....
" 48	.....	.....	.....	.....	.....		" 48	.....	.....	.....	.....	.....
" 65	2.0	.....	Combined with 100 mesh	.....	.....		" 65	4.5	2.80	7.4	6.8	14.6	
" 100	1.9	.38	5.4	19.0	14.0		" 100	9.1	1.62	5.2	11.6	17.4	
" 150	.....	.....	.....	.....	.....		" 150	9.1	1.62	5.2	11.6	17.4	
" 200	.....	.....	.....	.....	.....		" 200	13.6	.82	5.7	21.2	17.3	
thru200	.....	.....	.....	.....	.....		thru200	72.8	.32	6.5	32.2	14.0	
Calculated average assay	.35	6.4	20.2	22.6			Calculated average assay	.62	6.3	27.7	14.8		

PERCENTAGES OF TOTAL CONTENTS IN VARIOUS SIZE PRODUCTS

FEED							DISCHARGE							
Mesh	Au.	Ag.	Pb.	Zn.	Mesh	Au.	Ag.	Pb.	Zn.	Mesh	Au.	Ag.	Pb.	Zn.
+10.....	74.6	66.0	71.6	68.5	+48 to +100	20.4	5.3	1.1	4.4	+100	.....	.....	.....	.....
+14.....	9.9	19.0	12.8	16.1	+150	23.6	7.5	3.8	10.7	+150	.....	.....	.....	.....
+20.....	7.3	7.9	7.9	9.5	+200	18.0	12.3	10.4	15.9	+200	.....	.....	.....	.....
+28.....	5.0	3.8	4.0	3.5	-200	37.7	75.0	84.7	68.9	-200	.....	.....	.....	.....
+35 and below	4.2	3.3	3.7	2.4										
100.0														

Screen analysis (2) also illustrates in a rather striking way the tendency for the total gold in discharge to exceed that in the feed. There were 11 screen sizes in each case, and in all but one size, when feed and discharge ran about the same, the gold was far higher in the discharge. The average gold indicated by the assays in the feed was 0.15 ounce, and in the discharge 0.44 ounce. Substituting for the highest assay in the discharge the average of the assays on the adjacent

sizes, the average of the discharge is reduced to 0.37 ounce, or two and one-half times the average of the feed.

We are now installing a pair of rolls, to be set close, to recrush these soft middlings, and shall hold the 4-foot Hardinge in reserve, for use when some of the other machines are out of commission for repairs.

Value of Screen Analyses

I have always been disinclined to attach overmuch weight to the details of screen analyses, excepting as to their general trend. If we take two identical samples, and compare duplicate screen analyses on them, made by different individuals, or even by the same person, we usually find wide variations in the results. Such differences indeed we may expect, in view of the rectangular apertures employed, and the varied forms of the particles to be screened. When a particle is, in every section but one, larger than the screen aperture, and in that one section just small enough to pass through the aperture, but only if rightly oriented, it is clear that particle and aperture may be brought into contact perhaps a hundred times before it will pass, and in the meantime sharp edges of many other particles, which at first would not have passed through, may have become worn down sufficiently to enable them to pass.

The difference between screen analyses performed wet and dry is well known.

Some of the spotty gold assays which have crept into our screen analyses may perhaps be due to the alternate use, for such tests, on rich and poor material, of the same nests of screens. In the finer sizes, a considerable proportion of the apertures becomes blinded, and if there are small particles of gold included in the material thus held in the screen, they may become dislodged when screening subsequent samples, so introducing erratic assays into the latter. As far as possible, however, we guard against this contingency by using a different set of testing screens for high-grade and low-grade mill work.

I referred above to occurrences of free coarse gold in the mill. So far as I can learn, during the entire 30 years of the mine's history, no specimen showing free gold has ever been seen. Yet the existence of pockets of free gold has been inferred from the occasional erratic bunches of extremely rich ore encountered, and the unusually spotty assays, which suggested that the rich ore could not exist in the form of telluride or other friable material.

At intervals, in the mill, we have found sudden evidences of coarse gold. The gold ordinarily caught on the plates is fine; by dissolving the amalgam with nitric acid, 82 per cent. was found to pass a 100-mesh screen. Its fineness, moreover, averages only 550. The other kind of gold is of about 650 fineness, and coarse—nearly all of it over 20-mesh. It is mostly caught on the carpets used below the plates, and on the first few riffles of the Card tables which are fed from the two first spigots of the classified line. Both these products are taken direct in pipes to a grinding pan of arastral type, with a bottom paved with silex bricks, and a stone drag, where they are ground continuously with quicksilver; the amalgam being cleaned out daily through a spout in the bottom, and the overflow settled and added to the high-grade concentrate. In this way we avoid difficulty in sampling and selling unnecessarily spotty concentrates, and furthermore are able to keep slightly better control of the gold contents throughout the system.

At times on the jig-beds, we have been able to sort out quite a number of pounds of metallic particles, attached sometimes to quartz and sulphide minerals.

These range in size from 2 mm.—the mesh of the jigscreens used—up to 1/3 inch. One or two such nuggets have been found in the trommels over 1/2 inch in diameter, nearly all of gold of about 670 fineness.

Methods of Calculating Recovery

There has been a great deal of discussion in the technical press during the past year with reference to methods of calculating rates of extraction in mill work. We have the partisans of the method of calculating from weights and assays of tailing, or from assays entirely, excluding weights, together with products, on one hand, and on the other hand, those who insist on the necessity for sampling heads, which usually requires a sampling plant. To me it seems a question to be decided on the merits of each individual case. Poor samples of mill feed are worth very little; and accurate sampling usually adds materially to costs of construction and operation. Samples of tailing can usually be obtained with relative accuracy; and products must be accurately sampled for purposes of sale, so that their accurate determination is chargeable, not to cost of mill operation, but to cost of realizing products. Where only one or two products are to be marketed, it seems to me that the method of calculating heads is admissible; the objection to its use comes with more validity from the general management, which may require the independent check on the mine work which is afforded by actual sampling of the mill heads.

Where on the other hand we have many metals to be recovered, and many products to be made, which are marketed at irregular intervals, samples of headings become almost indispensable in order to control the daily work. Even with this help, in the case of the plant which I have in mind, the locked-up material in sumps, mills, etc., so affects the daily tailings that (especially as to gold content) it does not always correspond with the daily feed. This is strikingly illustrated by the fact that, when we have a daily feed which happens to run up in gold, the tailing often shows no increase; but it does so for several days thereafter.

In the course of the discussion above referred to, Mr. W. S. Welton objected to the use of tailing assays in figuring savings, for the reason that the water decanted from the tailing sample "invariably contains higher values than the material which settles and accordingly carries away a large percentage in suspension." To quote from his article in the *Engineering and Mining Journal* of July 12, 1913: "Under working conditions, it is impossible to ascertain directly the real value of the tailing.

"From the moment concentration commences, the water made use of carries off mineral of value, and this continues all through the process. The amount of floating mineral will vary with the fineness of division of the particles, degree of concentration, amount of water used, and inclination of the tables, or with the rapidity of concentration. The effect of these circumstances is to cause the settled tailing to be invariably of lower assay value than if there was no float."

A little further on Mr. Welton states that "to estimate the extraction" it is "clearly necessary to know either the correct value of the mill feed or of the tailing," and in view of the difficulty he considers to exist in sampling the tailing recommends dependence on sampling the feed.

This contention was supported by a number of assays taken in the course of some concentration tests on silver ores. It would, however, be difficult to find a more striking case of the fallacies which may result when one argues from the particular case to the general. In the first place, while the suspended slime tailing from concentration is usually of higher assay than the sand, it

is not "invariably" or necessarily so—in my own experience I have found several instances where the contrary was true. In the second place, if proper time is allowed for settling, and lime or other aid to settling made use of, the loss in suspension is usually small. Finally, as the ease of taking correct samples increases with the fineness of the particles, there is no excuse for not getting accurate samples of the water, plus whatever matter it may hold in suspension; nor is there any insuperable difficulty in evaporating the entire sample to dryness, water and all. What we do in practice is to settle the sample with lime, decant the clear water, and evaporate the rest to dryness. But as a further precaution, we occasionally save the whole of the water decanted, evaporate it and assay the residue. In the case of the Mary Murphy, this is much richer than the sand tailings; but the proportion of solids is so small that it makes little difference.

The last time this test was made the proportion of solids in the decanted water was 0.25 per cent., which assayed:

Gold, trace; silver, 1.4 ounces; lead, 4 per cent.; zinc, 18.7 per cent.

The weight of water is about fifteen times that of the dry pulp, so that it is easily seen that the loss suspended in the water is negligible. I think every mill should make such tests at intervals, in order to guard against a peculiarly insidious form of loss; but in my experience it is rarely the case that the inaccuracy in tailing samples caused thereby is of any moment, assuming that the tailing is properly settled.

There are three essentially different ways in which to calculate mill savings: from head and tailing, from head and products, and from products and tailing. In simple mills, recovering but one or two kinds of product, it is a good plan to calculate the saving in all of these three ways, and compare the results. This is an excellent way of testing the accuracy of the sampling all through; and personally, although my own experience has generally been that I was quite unable to obtain the same result with the different methods, yet I have always thought it a very admirable plan. Nothing else calls your attention so forcibly and at the same time so promptly to the weak points of your sampling work. Even with the most complicated mill systems, it is well to take stock in this way at intervals.

Where owing to expense or other reasons only part of the sampling can be done automatically, it is clear that the tailing should be selected for this; because, after all, what primarily concerns the mill man is what he is losing, and how far it will pay him to follow it. The products are less essential to watch, because the cash account directs attention to them in the most forcible way possible; and also because the methods of sale usually ensure systematic sampling and record, even without conscious attention on the part of the operator.

It is frequently forgotten that to calculate the percentage of saving is, in itself, of no value. What we really want to know is, what is contained in the material that we are losing, and to what extent is it worth while to pursue it farther. If we are throwing away \$10 per ton from a \$40 ore, we are obviously losing what, under most conditions, it will pay to save. If we are losing \$1 from \$4 ore, it will rarely pay to attempt to recover it. Yet the percentage of saving is the same in each case.

Peruvian copper production for 1913 amounted to 27,940 metric tons, or say 27,500 English tons, an increase of 100 English tons over 1912. The output in metric tons was made up as follows: Bars, 20,340; matte, 4462; shipping ores, 3138.

Soot-Fall Study of Pittsburgh

BY JOHN O'CONNOR, JR.

In two interesting papers contributed to your journal by John B. C. Kershaw,¹ mention was made of the fact that a study of the soot-fall of Pittsburgh had been carried on in connection with the "Smoke Investigation" of the Mellon Institute, University of Pittsburgh.

The study was made by Dr. R. C. Benner, the Chemist of the Investigation. Dr. Benner was assisted by George Edward Bost. The study began in April, 1912, and extended over a period of a year. Twelve stations were selected in different parts of the city and samples of the soot-fall were secured by exposing jars on the roofs of buildings. Glass jars about 4" x 10" were used in summer, and copper cans, tinned inside, in the winter.

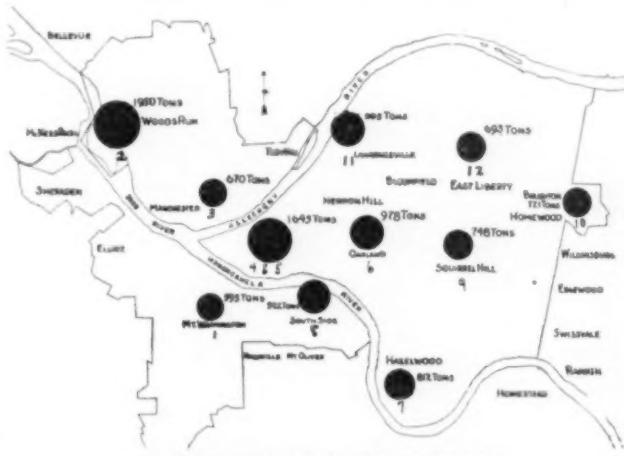
The jars were exposed for a month at a time. When a jar was brought to the laboratory, a 100 c.c. sample of the water was taken and tested for acidity with methyl-orange. If acid were found to be present, it was titrated with standard Na_2CO_3 . The total volume of the monthly sample was determined and the total acid calculated. The month's sample was then evaporated and weighed in a porcelain dish, placed on the water bath, heated in the steam oven about 18 hours, dried in a dessicator and weighed. 1.0000 Gram of the year's dried sample from each station (of stations 2, 4 and 5, 2.0000 Grams each), was wrapped securely in a quantitative filter paper and extracted with ether in the Soxhlet extractor to determine the tar content. The extracted soot was ashed and weighed and the iron in the ash was determined by standard potassium permanganate. Table I shows the monthly soot-fall in grams at the different stations. The total soot-fall in grams for each station is also given and below the table is the calculated soot-fall in tons per square inch per year (See Map).

Table III shows the calculated amount in tons at each station, of tar, fixed carbon, ash and iron.

TABLE III.

Sta. No.	SOOT-FALL IN TONS PER SQUARE MILE PER YEAR Composition of Soot				Total Tons
	Tar Tons	Fixed carbon Tons	Ash Tons	Fe_2O_3 Tons	
1	13	131	306	145	595
2	16	713	809	412	1,950
3	10	202	189	269	670
4	19	417	844	380	1,660
5	21	357	704	548	1,630
6	4	322	343	309	978
7	8	300	309	195	812
8	7	286	419	210	922
9	5	211	344	188	748
10	3	274	336	108	721
11	8	391	378	218	995
12	4	200	333	153	693

It is unfortunate that these figures cannot be compared with those obtained elsewhere, as, for instance,



SOOT FALL MAP OF PITTSBURGH

in London, Leeds, and Glasgow, because the method used in each place was different. Mr. Kershaw's plea for the adoption of a uniform system as that sug-

TABLE I.
PITTSBURGH'S SOOT-FALL SAMPLES IN GRAMS PER MONTH, APRIL, 1912, TO APRIL, 1913.
STATION NUMBERS

Month	1	2	3	4	5	6	7	8	9	10	11	12
1912												
April	3806	.5106	.2722	.5308	.5501	.4186	.1184	.2596	.1821	.1341	.2599	.1603
May	1081	.4146	.1142	.5198	.5882	.0873	.1384	.1915	.1332	.1192	.1676	.2778
June	2552	.5714	.2752	.4872	.4000	.3604	.2142	.3306	.1863	.1374	.2026	.1315
July	1450	.6924	.2570	.3900	.5520	.2282	.2030	.3364	.1732	.1564	.2078	.1938
August	1104	.5154	.1460	.2608	.3570	.1828	.2022	.2266	.1732	.1142	.2024	.1210
Sept.	1114	.5038	.1910	.2022	.3278	.1830	.1832	.2040	.1826	.1282	.2136	.1426
Oct.	1380	.5610	.2182	.3124	.4622	.2488 ¹	.2072	.3254	.1664	.1636	.2942	.1554
Nov.	0526	.7700	.1290	.2188	.3860	.2166	.2076	.1734	.1586	.1836	.2088	.1742
Dec.	1380	.7522	.3428	.4896	.3788	.3988	.2860	.1484	.4282	.3702	.4276	.2518
1913												
Jan.	1278	.5232	.2660	.6398	.2828	.2742	.3092	.2456	.2094 ²	.3154	.3206	.1948
Feb.	1034	.6200	.2642	.4574	.3746	.2042	.0914	.1462	.1278	.1420	.2894	.1242
March	1550	.5438	.1956	.5876	.3342	.1972	.3236	.3346	.1750	.2462	.1924	.1946
Total sample	1,8255	6,9784	2,6814	5,0964	4,9937	3,0001	2,4846	2,9223	2,2960	2,2075	3,0469	2,1220
Tons per sq. mile	595	1,950	670	1,660	1,630	978	812	922	748	721	995	693

¹The October jar from station No. 6 was broken, and the weight of the soot-fall for this month was calculated by taking the average monthly soot-fall for the other ten stations during the entire year, combined with the average monthly soot-fall for station No. 6 for 11 months.

²The January sample from station No. 9 froze and the jar was broken. The weight of the soot-fall was calculated for the month of January by taking the average monthly soot-fall for the other 10 stations during the entire year, combined with the average monthly soot-fall for station No. 9 for all eleven months.

Table II shows the per cent. analysis of the year's sample for tar, ash, fixed carbon, iron in the ash, and iron in the deposit.

gested by the committee named at the "International Smoke Abatement Exhibition and Conference," held in London, in March, 1912, becomes apparent at once.

TABLE II—PER CENT ANALYSIS OF YEAR'S SAMPLE OF EACH STATION

Number of Station	1	2	3	4	5	6	7	8	9	10	11	12
Tar	2.19	0.82	1.56	1.12	1.26	0.36	1.00	0.74	0.62	0.42	0.76	1.04
Ash	75.84	62.60	68.30	73.77	76.82	66.68	61.94	68.20	71.16	61.42	59.96	70.14
Fixed carbon	21.97	36.58	30.14	25.11	21.92	32.96	37.06	31.06	28.22	38.16	39.28	28.82
Fe_2O_3 in ash	32.08	33.73	58.78	30.98	43.66	47.44	38.44	33.38	35.42	24.05	36.52	31.47
Fe_2O_3 in deposit	24.30	21.10	40.10	22.90	33.60	31.60	23.80	22.80	25.20	14.80	21.90	22.10

¹Methods for investigating and recording atmospheric impurities, including the soot and dust suspended in the atmosphere, June, 1913, Vol. XI, No. 6, p. 339.

Notes on the standard apparatus and method for measuring the amount and character of atmospheric pollution, November, 1913, Vol. XI, No. 11, p. 615.

At the Convention of the "International Association for the Prevention of Smoke," held in Pittsburgh, in September, 1913, at the suggestion of Bailie Smith of Glasgow, Scotland, a committee was appointed of

which Mr. E. P. Roberts, the Smoke Inspector of Cleveland, was made chairman, to induce cities of the United States to take up the method suggested in England.

It is to be hoped, that this committee will be successful in its work and that in the near future cities of the United States will be able to compete by means of a uniform method, in an effort to show a low atmospheric pollution.

Mellon Institute of Industrial Research,
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A Successful Method of Amalgamating in Cyanide Solution

BY JOHN RANDALL

In case coarse gold is encountered in the cyanidation of ore, the question of amalgamation is not so important as formerly. When separate treatment of sand and slime was the general practice the question was quite important, but the problem was never satisfactorily solved. With the prevalence of all-sliming the case is quite different. The ore travels in a closed circuit through the fine grinder and classifier until reduced to slime, and any coarse gold which may happen to be in the pulp is thus "worn out" and gives no trouble in the extraction department. Therefore, in all-sliming mills it is considered good practise to simplify the process by cutting out amalgamation, even when the ore contains coarse gold.

However, there are cases in which it is best to treat a part of the ore as sand, and then if it contains coarse gold the question of amalgamation comes up. To crush in water, amalgamate, dewater and then treat with solution occasions a loss of cyanide besides complicating the process; while amalgamating in cyanide solution has its drawbacks. In the latter case we have the gold cleaned and brightened by the cyanide solution and in the very best possible condition for amalgamation, but we are confronted by new difficulties. The solution attacks the plates, rapidly eating them away, while the amalgam is hardened by the dissolution of the mercury until it becomes unmanageable and the plates inefficient. The difficulties encountered have generally been sufficient to result in the abandonment of amalgamation in cyanide solution after many careful and persistent efforts.

It is the object of this article to bring into notice a phase of the subject which seems to have escaped general attention.

It is well known that if metallic sodium be mixed with mercury and immersed in a watery solution the action of the sodium in going into solution as NaOH at the surface of the mercury will produce practically the same result as that occurring at the cathode of an electrolytic cell. If there is gold or other metals in the solution they will be deposited upon the surface of the mercury and amalgamated. But in plate-amalgamation the mercury and sodium is spread out into such an exceedingly thin film that the sodium is rapidly oxidized and carried off, the good effect of it being noticeable for only a very short time after dressing the plates. This is the main reason why amalgamators generally regard sodium as of little or no value.

Riffles Substituted for Plates

However, if riffles containing mercury be substituted for plates the last named difficulty is overcome, and it is possible to keep the quantity of sodium in the mercury fairly constant. Some time ago the writer was in charge of a mill, treating sand and slime separately, where gold nuggets the size of a pea were sometimes found, although the ore averaged a little below \$10 per

ton gold. The ore was a weathered dump and contained some copper as azurite, but no native copper. The crushing was done in solution in a Chilean mill through 16-mesh screens. The mill was provided with plates, but they were taken out and riffles were substituted.

In cleaning up it was found that the greater part of the amalgam was so fine that it could be squeezed through chamois leather, and the bullion from the riffles was found to contain about two pounds of copper for each ounce of gold and silver. It is evident that the copper was deposited from the solution, and that in addition to recovering free gold that passed through the screens, the riffles had been of service in mitigating troubles arising from copper in the zinc boxes.

It was aimed to keep the amount of sodium just below the point where the mercury would amalgamate a freshly brightened iron nail. To accomplish this some mercury containing a large amount of sodium amalgam was kept on hand in a dry, glass-stoppered bottle and a determined amount of this put into the riffles every four hours. No mercury was detected in the solution, and as none was floured, a weighing at the end of the run showed no loss except what might be expected in retorting.

Returning Part of Riffles Discharge by Tailing Wheel

In operating riffles it is found that those of the best design will choke when the feed is temporarily diminished below full capacity, and some trouble is experienced in getting them started again. This trouble may be obviated by placing a small tailing wheel in such a manner that it will return a variable amount of the outflow back to the head of the riffles as shown in Fig. 1. By this means riffles of comparatively large

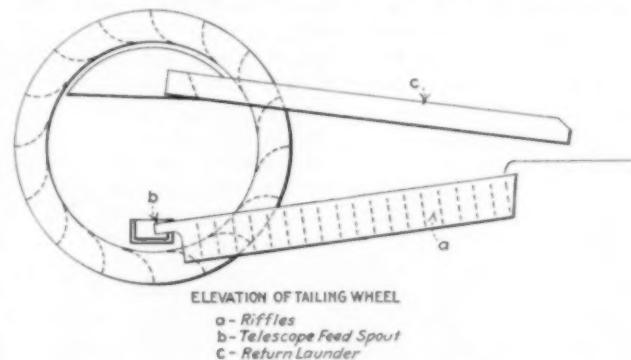


FIG. 1—USE OF TAILING WHEEL TO RETURN PART OF RIFFLE DISCHARGE

capacity may be operated on a small amount of pulp. A section of the feed spout may be made to slide in telescope style, or a movable partition may be placed in the spout to cut out a variable amount of pulp.

I think it very doubtful if it would pay anybody to make riffles should they desire to use them with mercury, for this or any other mill purpose. The Pierce riffles, called the Pierce amalgamator, can be depended upon if given the proper amount of feed, and the sodium will protect the metal parts. They look somewhat expensive in first cost, but any riffles that will hold mercury and not pack with sand are open to the same objection. In operating riffles it is quite necessary to have a screen above them to intercept gravel that may occasionally come from a broken mill screen.

Boulder, Colo.

The Alaska Gold Company expects to have its immense mill ready for operation before the end of this year as planned. Excavations have been completed and erection of steel should commence this month.

Mechanical Refrigeration—III

The Absorption Refrigerating Machine

BY H. J. MACINTIRE

The absorption refrigerating machine, although one of the first designs for artificial cooling, has only recently been given the careful attention necessary for economic results, but now its construction has been so perfected as to give it an unassailable place in the refrigerating industry. Yet the operation and details of the cycle are so foreign to common steam-engine practice as to cause considerable trouble to those unfamiliar with it. It is hoped that the following will be so presented as to make the working of the machine seem as perfectly clear and simple as it really is.

Before taking up the design of the absorption machine in detail the few similarities to the compression machine and the notable differences of the two will first be pointed out. The condenser and cooler are identical in both machines. The compression machine uses an anhydrous refrigerant, whereas the absorption machine uses ammonia only—part of the time as a solution in water and the remainder of the time as nearly anhydrous ammonia. The compression machine compresses the vapor by the displacement of the piston driven by a heat engine or electric motor. The absorption machine utilizes the heat in the steam directly to separate the ammonia out of its solution (thereby leaving a weak aqua in the still) and to drive it finally into the condenser where it is condensed by the action of cooling water as in the other type of machine. In order to provide continuity of action the vapor from the cooler must be returned to the still or generator by com-

dehydrator. The analyzer and dehydrator also act as a check to excessive ebullition in the still and tend to prevent the aqua of the generator from boiling into the condenser, which would preclude further refrigeration. Drips from the dehydrator pass by gravity into the generator.

The vapor from the cooler must be returned to the generator in the form of a solution or strong aqua. To do this the weak aqua from the generator is first cooled and then sent into the absorber where it comes into intimate contact with the vapor from the cooler. The pressure in the absorber is but slightly lower than that in the cooler (some 10 lb. to 35 lb. absolute) and the temperature of the weak aqua entering the cooler is from 80 deg. Fahr. to 110 deg. Fahr. The result is that the affinity of the cool weak aqua is quite strong for the ammonia and a stronger aqua results with a liberation of heat which must be removed by cooling water or the temperature will rise and prevent satisfactory operation. The strong aqua, cooled to about 90 deg. Fahr., and at a pressure of one or two atmospheres must be returned to the generator under a pressure of eight or twelve atmospheres. As the weak aqua had to be cooled before admittance to the absorber and the strong aqua requires heating before being pumped into the generator very excellent results are obtained by the use of a counter-flow exchanger—usually of the double-pipe (one pipe within the other) construction. The hot weak aqua then proceeds from the generator, through the exchanger, where it gives up its heat to the strong aqua and then enters the absorber. The heated strong aqua is piped into the upper part of the analyzer, where it flows by gravity into the generator and cools the

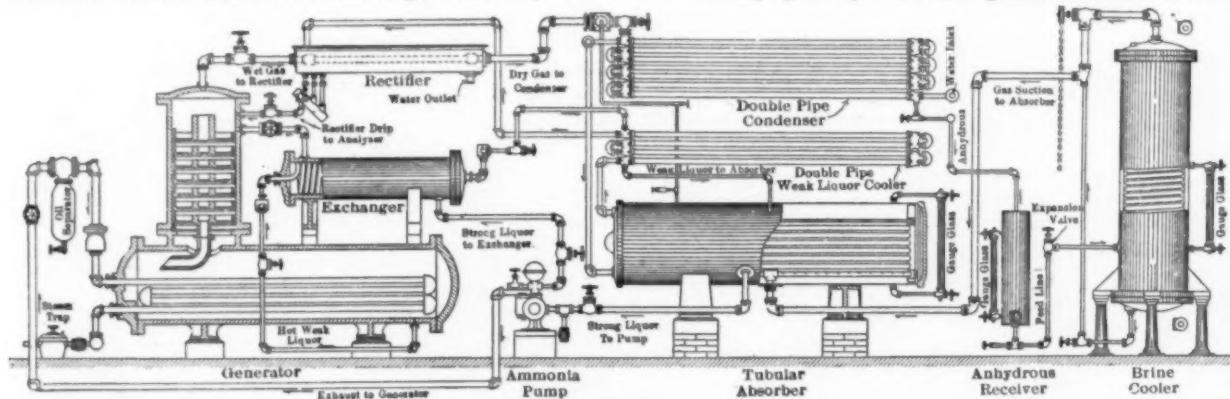


FIG. 1

bining it in solution again with the weak aqua from the generator. The absorption machine has no moving parts except a small pump, and uses the heat energy in the steam. There is, in fact, no reason why atmospheric exhaust steam may not be used to advantage in most cases, provided the absorption machine is designed with the necessary heating surfaces in the generator for this condition of operation.

THE ABSORPTION CYCLE

Let us refer to Fig. 1 and consider the absorption cycle in detail. The generator is usually a cylindrical shell containing a solution of ammonia, from 30 per cent to 35 per cent in weight, and a number of steam coils connected in front to steam headers. The action of heat tends to dissociate the ammonia from the solution, and the ammonia, as well as some water vapor (under a pressure slightly in excess of the condenser pressure) pass into the upper portions of the generator called the analyzer. In the latter is a counter-current of strong aqua colder than the vapor arising which condenses most of the water vapor and cools the ammonia vapor of some of its superheat, an operation which is nearly completed in the water or air-cooled

ascending hot gases being driven off from the generator.

In summing up, the analyzer and the dehydrator provide a means for moderate cooling of the ammonia vapor and nearly perfect separation of the water content. The exchanger increases the efficiency of the plant by saving steam in the generator and cooling water in the absorber. The generator and the absorber are the two important, distinctive absorption features. The condenser and cooler are identical with those used for the compression form of refrigerating machine.

Keeping in mind the general construction of the two principal designs of refrigerating machines and their cycles, it is desirable now to make a brief comparison of them. The compression machine utilizes the expansive force of the steam which does work on a piston, which likewise in turn does work on the refrigerating medium. The steam is usually taken at boiler pressure into the cylinder of the steam engine and is exhausted (except for the larger machines) into the atmosphere or into heating coils at nearly atmospheric pressure. The percentage of heat in the steam converted into useful work is usually not in excess of 10 per cent and

often is much less. The absorption machine transfers the heat in the steam to the aqua in the generator. As the steam condenses, the heat given up to the aqua is between 900 and 1000 B.t.u. per pound, and the efficiency of the conversion is approximately 75 per cent.

The greatest point in favor of the absorption machine, speaking economically, is that it may be designed to use exhaust steam, and requires power only for the strong aqua pump and such other auxiliary apparatus as apply to the particular installation—such as brine-circulating and deep-well pumps, fan for the circulation of air, etc., and the exhaust from these (if steam-driven) may be employed in the generator. Also in a properly designed and compact grouping of the separate machines the decrease of the cooler pressure does not offer any difficulties and the cost of a ton of refrigeration (cooling at the rate of 200 B.t.u. per minute) does not increase very much with low refrigerating temperatures. Brine temperatures of —10 deg. Fahr. or —20 deg. Fahr. are readily and economically obtained. The absorption machine, however, is more costly as a rule and covers more space than an equally sized compression machine. Considerably more ammonia is required for charging, and the loss due to leaks and disintegration is greater.

As has been stated exhaust steam may be used in the absorption machine, and also that 75 per cent to 80 per cent of the heat in the steam passes into the aqua of the generator. Such being the case, it would seem at first that the absorption machine is by far the most economical of all refrigerating machines and that where exhaust steam was a by-product the compression machine could not possibly be a competitor. Yet, although certain advantages can be claimed for the absorption machine, it does not give in practice the economy of operation that it would seem capable of. According to competitive tests it has been found that about 30 lb. of steam per hour per ton of refrigeration is required for either type of refrigerating machine.

The reason for this lack of good showing on the part of the absorption machine may be seen by considering the analysis of the heat necessary for the operation of the generator per pound of ammonia condensed in the condenser, taken from an actual test.

1. Heat of solution at average concentration of aqua (31.8%)	= — 193.0
2. Difference in heat of the liquid above saturation (129.7 — 63.7 × 1.154)	= + 77.4
3. Heat of vaporization at temperature of saturation (from condenser pressure)	= — 518.1
4. Heat necessary to superheat the vapor (0.52 × [152.0 — 62.7])	= — 47.5
5. Heat necessary to heat the strong aqua to the tem- perature of the outgoing weak aqua (6.65 × 50.1 × 1.048)	= — 349.0
Total	— 1030.2

This very large total of 1030 B.t.u. per pound of ammonia condensed requires from 26 lb. to 34 lb. of steam per ton of refrigeration per hour, depending on the operating conditions. Items 1, 3 and 4 are inevitable and vary but little with different conditions of operation. Item 5 could be eliminated by supplying the strong aqua to the generator at the temperature of the aqua leaving the generator. As this is impossible without supplying additional heat, the only means of making this item small is to have little aqua in circulation per pound of ammonia condensed, namely, by the use of large differences in the concentrations of the weak and strong aqua. Usually the number of pounds of weak aqua circulated per pound of ammonia condensed is much greater than in the case above (6.65), especially if care is not given to the operation of the machine. However, where exhaust steam is available and cannot be otherwise used, the absorption machine is generally the best refrigerating machine to employ.

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The Igneous Concentration of Metallic Values from Mixed Sulphides—I.

BY F. L. CLERC

In the earlier paper, on the "Igneous Concentration of Zinc Ores,"¹ I directed attention to three well known processes of manufacturing zinc pigments, or of pigments containing zinc, and suggested modifications in certain particulars, to adapt them to the concentration of zinc as a sublimed product.

In reference to my present subject, I made the following statement: "Much is to be expected from pyritic smelting if concentration (of values) at the top of the furnace becomes an object of consideration."

In returning to the subject, it may be well to state clearly at the outset what I shall attempt to do, and what I wish to avoid even the appearance of trying to do.

The igneous concentration of copper in the form of matte, from ores carrying only a few per cent of copper, and the production of metallic copper from these mattes, has had a phenomenal development in the last twenty years, and has established itself in all quarters of the world.

I do not propose to write even an outline history of this development. Nor do I propose to examine into technical details, or to try to explain variations in practice imposed by local conditions.

The idea underlying much of this progress is to utilize, as far as is practicable, the heat evolved by the rapid oxidation of sulphur and the metal with which it is combined, to carry on the smelting operation. The object of metallurgy is to separate a metal from its ores, and in some cases from other metals. Carbonaceous fuel is needed in most igneous processes to supply the heat required; in so far as this heat can be effectively generated by metals and metalloids, less carbon will be required.

Relation of Pyritic Processes to the Igneous Concentration of Zinc

In applying this principle of the generation of heat by the rapid oxidation of metallic sulphides to the closely related subject of the concentration of zinc by sublimation from mixed sulphides, it is important to know what it has done for copper metallurgy, and to inquire a little into its theory, how it has affected practice, and along what lines it has been developed. There are two classes of metallurgists who are likely to become interested in the igneous concentration of zinc. First: Those copper smelters whose ores carry an appreciable amount of zinc; to them my treatment of the subject may appear superficial and inadequate. The other class are those who have to do with ores of zinc intimately mixed with other sulphides, but who have not had practical experience in copper smelting. These latter may find, by looking into the subject, that they can profitably make use of a source of heat which the copper smelters have quite fully utilized.

I propose then, in a very general review of the subject, to select a few notable events, as a traveler in a strange country marks his course by land marks. I choose as the events by which progress is marked public demonstrations on a commercial scale, which have been adequately reported upon.

The account here given of these demonstrations is taken from the Presidential address of Mr. Robt. C. Sticht read before the Australasian Association for the Advancement of Science, at the Adelaide meeting in January, 1907. By referring the reader to this address

¹Eng. and Min. Jnl., Jan. 13, 1912, p. 127.

for a connected story of the earlier investigations and discoveries, which prepared the way for these experiments, and for a connected account of what has been done since, I can bring my subject within the limits of a single article, and in some measure trace the application of the idea. The demonstrations chosen are: First. The experiments of three Russian metallurgists in Bessemerizing copper matte, the results of which were published in the Russian Mining Gazette of May, 1870, and also in *Berg und Hüttenmannische Zeitung* in 1871. Second. John Hollway's experiment with copper ores in 1878-9, reported to the Society of Arts February 12th (or 22d?), 1879. Third. The introduction of the process of Bessemerizing copper mattes at the Parrot Works in Montana under the supervision of agents of Manhés. Fourth. The revival of Hollway's process, with modifications adapting it to then prevailing conditions in Montana and Colorado, by W. L. Austin and others. Fifth. The establishment of a great copper industry at Mt. Lyell in Tasmania.

Definition of Terms. "Pyrite" or "Pyritic?"

Before recounting these events, it is desirable that a clear understanding should be reached as to the meaning of certain terms which must be used. These words are used by different authorities to convey different meanings. Thus we have "pyritic" smelting and "pyrite" smelting, also "pure" and "partial pyritic" smelting, or "pure" and "partial pyrite" smelting, a needless assortment of names, resulting in some confusion of meaning.

It has been urged by some against the adoption of "pyritic" smelting as a generic name to classify a group of allied processes, based on the utilization of the heat evolved by the rapid oxidation of sulphur and metallic bases, by means of an air blast, that this name was appropriated by John Percy for the iron-matting process, long practiced in Europe, in which unroasted iron sulphide was added to the charge for the purpose of collecting the precious metals it contained, in an iron matte. As these metals were extracted from the matte by means of lead, since a cupriferous lead bullion was troublesome to treat, copper was excluded from the charge as far as was practicable. The force of this objection is somewhat weakened by the now recognized fact that the heat of combustion of the iron sulphide was to some extent utilized to carry on the operation. Moreover, this process is not deposed from its proper class as one of the pyritic processes; it still holds its position as one variety of pyritic processes. It is not unusual in scientific classification, where a single species has been the sole representative of a genus, and is given a comprehensive name, to transfer this generic name to a class of similar things discovered later, which have to be classified, and to relate the first species reported to a subordinate position.

A more serious objection can be made to the name "pyrite" smelting. Pyrite is a name coined to accurately denote a particular mineral, FeS_2 , and distinguish it from other metallic sulphides occurring as ores, and include in mining and metallurgical parlance in the general term of "pyrites." Used as a noun in connection with smelting, the sense may be altered with the preposition required to correct the ellipsis. It is not the smelting of pyrite, nor the smelting with pyrite, nor even the smelting by pyrite, that conveys the meaning intended. Unless "pyrite" is used adjectively, and deprived of its specific meaning, a whole class of minerals more or less included under the popular name, pyrites, are excluded by definition from this process of treatment.

"Pyritic" is an adjective properly formed from pyrites. Like all adjectives, it cannot be understood in

an absolute sense. It qualifies a noun and reflects either an individual opinion or a principle of classification. "Pyritic" smelting, then, means smelting, best distinguished from other smelting in some way closely related to the group of minerals called pyrites. The definition of the genus will then determine what processes are included in it. This definition will not exclude the processes described as follows: "The practice of pyrite smelting is based upon the utilization of the heat derived from the combustion of sulphide ores, in a blast furnace, in contradistinction to the heat obtained directly from carbonaceous fuel."¹ Nor with this: "We will therefore call pyritic smelting the art or practice of smelting a charge, in which all the iron present is combined with sulphur to produce a ferrous silicate slag."² "The allowable amount of coke in the charge is considered immaterial. A distinction based on it is only conventional."³ On the other hand, it includes a number of closely allied processes. It will include the production of metallic copper from matte, the enrichment of mattes, as well as the production of mattes from the sulphide ores. These different processes can be distinguished from each other, but all are based on the same theory which is the standard of classification. Under this classification a furnace would not run one day on a *pure* pyritic process, and another day on a *partial* pyritic process, and we need not inquire as to the intention of the operator, or as to his knowledge of what is going on in his furnace.

Historical Events

The Russian experiments were under the direction of M. Semmennikow, governmental head of the department. After a few preliminary tests with small quantities at the Bogolowsk copper plant (1867), they were repeated on a larger scale at the steel works near by, at Watkinsk. These tests, as to the suitability of copper mattes for the Bessemerizing process, were carried on by A. von Jossa and N. Laletin. The results, as referred to by Mr. Sticht, may be summarized as follows: The tests were made in rather small charges, but in all 18,000 lb. of matte containing 31.5 per cent Cu were treated. Fifteen tests in all were made, including the enrichment of 31.5 per cent Cu mattes to 72-80 per cent Cu, and the further refinement to 80-95 per cent Cu. The final matte was worked up on the speissofen, according to the practice of the time. The experiments were made in an oval converter, designed for Bessemerizing pig iron, which had a height of 5 ft. and a greatest diameter of 4 ft. 2 in., which treated from 1600 to 2000 lb. of matte at each "blow." The air pressure used varied from 4 to 12 pounds per square inch. High pressure involved the ejection of molten material; low pressure resulted in the closing of the tuyeres, which necessitated frequent cleaning. There were seven tuyere bricks in the bottom of the converter, each of which contained five vertical openings $\frac{3}{8}$ of an inch in diameter. In some of the experiments, all except 6 to 10 of the openings at the bottom were closed, and two supplementary horizontal tuyeres, $1\frac{1}{2}$ inches in diameter, were inserted tangentially at the bottom.

The slag formed during the operation was lifted off in chilled layers, and was not skimmed or poured.

The attempts to bring 95% Cu mattes up to metallic copper were less favorable. This was probably due to the small amount of rich matte treated, in all 720 pounds were so used, and on pouring much of it remained as a skull adhering to the walls of the converter. With a larger charge, a greater proportion could have been poured. The expedient of "double banking," i. e.,

¹T. A. Rickard, *Purite Smelting*, p. 9.

²Geo. A. Guess, *Eng. and Min. Jnl.*, Jan. 13, 1912.

³Idem.

blowing successive charges before pouring was not tried. These Russian engineers clearly understood that a large part of the heat developed in the first stage of the operation (with low-grade mattes) came from the oxidation and slagging of the iron; the oxidation of Cu₂S to produce metallic copper being more important in the second stage. They clearly distinguished between the two stages by the end of phenomena of color and character of flame. They were influenced, perhaps unfortunately, by the tendency of the times, to experiment extensively with the injection of steam with the blast. They were somewhat hampered by the crudity of the apparatus employed, but even in this respect they were more fortunate than other early experimenters, and were especially qualified by their experience in Bessemerizing iron and converter manipulation to conduct these experiments. The cold matte was separately melted and run into the converter.

Their conclusions, in brief, are as follows:

Bessemerizing copper matte by means of superheated steam alone, or admixed with air, is scarcely practicable. Production of black copper, 95 per cent Cu, by the application of highly compressed air, is perfectly feasible, but likely to be unprofitable, partly because of wastage of copper and partly because of accretions of copper on the converter walls. But the process of Bessemerizing low-grade copper matte is deserving of the greatest attention, and may be of the greatest utility, under the following conditions: (a) The matte should be run hot into the converter; (b) the operation should only be continued to the point where the charge consists of one equivalent of Cu₂S to 0.12 of an equivalent of FeS; (c) the regulus should be brought up to black copper in the ordinary way, in a roaster furnace having a number of air tuyeres.

The advantages claimed by this new process, even thus restricted, were a notable saving of time, fuel and labor. Mr. Sticht sums up: "With these Russian experiments * * * the pneumatic process, as applied to copper mattes, was fairly launched. At all events, the availability of sulphide substances as sources of great heat under conditions which accelerate the chemical phenomena of ordinary copper smelting processes was completely established," etc.

John Hollway's experiments³ in treating ore were made with the use of low grade Rio Tinto pyrites, at Messrs. Cammell & Co.'s steel plant in 1878-9, the ordinary Bessemer paraphernalia being employed. The pyrites were melted down in a cupola furnace, and blown in regular 6 ton vessels, with 20-lb. air pressure. All phenomena were scientifically scrutinized; temperature, flame, composition of gas and molten products, etc. Among other things, he succeeded in running one converter on pyrites and quartz for fourteen consecutive hours, with repeated charging, and with the total exclusion of carbonaceous fuel, other than that used to provide the blast.

Altogether his trials demonstrated to the members of the Society of Arts, for whose benefit a special exhibition was given, "that pyrites carrying copper could be made self-smelting, and was a metallurgical fuel of the utmost efficiency; that the waste of its fuel qualities in current practice could be obviated; that a high ratio of copper concentration was achievable; that a complete utilization of atmospheric oxygen was affected," etc. Mr. Sticht regards these tests as a brilliant contribution to metallurgical art, and the report upon them as one of the classics of metallurgical literature.

The foregoing apparently successful commercial tests

³A New Application of Bessemer's Process of Rapid Oxidation, by Which Sulphides Are Utilized as Fuel. Read before the Society of Arts, Feb. 12 (or 22?), 1879.

by Semmenikow and Hollway were not immediately followed by the building up of a new metallurgical industry, but the underlying idea inspired other investigators like Manhés and David in France, who developed the Bessemerizing of mattes. Mr. Sticht attributes the rapid expansion of pyritic smelting since 1885 to the transplanting of the process to newer fields of activity where an abundance of suitable ore, and the ingenuity of metallurgists, unhampered by conservative traditions, offered most favorable conditions. The events to be noted are:

"Six converters of the permanent plant at the Parrot Silver & Copper Co.'s works, at Butte, Montana, were completed in 1885, at the instance of Mr. Franklin Ferrall, Pres't, and under the supervision of agents of M. Manhés. Subsequently, American inventive genius, favored by economic conditions, has improved on the construction of converters and all accessories, and upon their operation. The Bessemerizing of copper mattes was thus put on a sound basis. At first, the mattes treated were kept at 35 per cent Cu, later the advantage of a 50 per cent Cu matte was seen, and this grade of matte was produced." Many workers contributed to this rapid advance. It is quite apart from my theme to award praise or to enter upon the question of priority.

To follow Mr. Sticht still further:

The urgent demands for copper mattes to keep the converters in operation directed attention anew to Hollway's experiments. "The interest in the rapid oxidation of sulphide ores, as spontaneous fuels, was revived by Mr. W. L. Austin. He with others took up the 'raw smelting' innovation, and perfected it in the new light, etc. Following in the footsteps of Mr. Hollway, and modernizing his operative scheme, the true pneumatic pyritic principle, but supported by the use of a hot blast, was at last brought to some degree of practical perfection. This was effected in Montana between 1887 and 1891, and was subsequently further pursued in Colorado."

"It was, however, reserved for Australia to demonstrate finally and conclusively that 'pyritic smelting' * * * is wholly suitable for copper ores of any grade, and is not afflicted with a greater wastefulness through scorification, or other source, than current older methods, etc. The special opportunity came at Mt. Lyell, Tasmania, in 1896, etc."

From these two nurseries, the mining regions of the Rocky Mountain states, and of Australia, the newly established industry has spread rapidly over nearly all the copper mining districts of the world. In each new field it has advanced along special lines, more or less determined by local conditions, and must be studied in each particular case in connection with these conditions.

Progress of Pyritic Processes

The progress in pyritic smelting of copper ores, as distinguished from Bessemerizing copper mattes, may be profitably followed in the discussions of the subject carried on in the columns of the *Engineering & Mining Journal*, 1903-1905. The principal papers were published in book form under the title of "Pyrite Smelting." These carefully considered opinions of thirty or more competent metallurgists, bring out most clearly the effect of local conditions in modifying operative details. Nevertheless, there is a general concurrence of opinion upon the underlying principle.

Of the ten questions under discussion, I will only consider three: the use of a heated blast; the addition of coke to the charge, and the effect of zinc sulphide in the charge. It was generally admitted that warm or hot blast is desirable in almost every case, if it does not cost too much; that it is indispensable in some cases,

and can be avoided in others. For particulars, the papers themselves should be consulted. Coke has been entirely omitted in some campaigns. In others it has been reduced to between 1 per cent and 1½ per cent of the charge, using a cold blast, when the ore ran high in pyrite. In general, smelting with 4 per cent of coke is considered good work. The practical question is this: Whether it is cheaper to furnish a hot blast, and save coke, or to use a few more per cent of coke and put up with the inconveniences which follow its use. The drawbacks to heating the blast are the cost of the hot-blast stoves and their low efficiency in raising the temperature of the blast. In pyritic smelting the gases issuing from the furnace contain too much sulphur to be used to fire the stoves, so that additional carbonaceous fuel must be burned. Some of the objections to coke in the charge, apart from its cost, and the difficulty of obtaining a suitable quality of it, in some localities, are as follows: Theoretically, and in practice, the reducing activity of carbon antagonizes the rapid oxidation of the furnace charge, which is the basis of pyritic smelting. So far, its use is irrational, but in the present state of the metallurgical art it may be admitted that in some cases it is indispensable. To burn the coke an additional amount of oxygen must be blown into the furnace, which is accompanied with nearly four times its volume of nitrogen, which makes necessary a large blast installation. As Dr. Peters expresses it, "To obtain this oxidizing atmosphere we must reduce the amount of coke until, when blowing a reasonable blast into the furnace, there will be enough oxygen, not only to burn the coke, but also to produce a highly oxidizing atmosphere with which to burn the sulphide; for, when an atom of oxygen has to choose between an atom of glowing coke and an atom of glowing sulphide it prefers to combine with the coke and the sulphide simply melts as ferrous sulphide and goes into the matte as such, and it is only the excess of oxygen that acts on the sulphide." The result is an increased amount of matte and a lower ratio of concentration. The heat supplied by the coke and its reducing action is apt to be developed at a level in the furnace where they are not desired. The occurrence of iron sows and the accumulation of Fe_3O_4 (magnetic oxide) reported by several observers may be due to local reactions with the coke. On the other hand, Dr. Peters considers the reaction $FeS + 2FeO = 3Fe + SO_2$, as possible. This would not occur if free silica to combine with the iron oxide were present. In connection with a hot blast and the use of coke, Messrs. Lynn & Keeney, metallurgists connected with the U. S. Bureau of Mines, suggested in a paper¹ read at the September, 1913, meeting of the A. I. M. E. at Butte, the question "Whether electric heat may be used to replace the heat which is derived from the combustion of coke in pyrite and semi-pyrite processes" * * * "would it be possible and commercially feasible to carry out these processes in an electric furnace using a blast, obtaining as much heat as possible from the oxidation of the sulphur and iron and supplying by electrical energy whatever additional heat might be needed." In the discussion of this paper² it was suggested that this heat could be most effectively applied to the blast.

The effect of zinc in the charge is generally considered negligible if it does not exceed 10 per cent to 12 per cent of the ore. It is admitted that some of it escapes at the top of the furnace, but in general an attempt is made to throw it into the slag. The fact that zinc sulphide has a considerable calorific value, as a

metallurgical fuel, is however clearly brought out in the discussion.

Further Application of Rapid Oxidation Processes

Mr. Sticht emphasises the fact that the utilization of the heat developed by the rapid oxidation of metals and metalloids in the charge by means of an injected blast of air has found application beyond the boundaries of steel and copper metallurgy. "Witness the revolution already wrought in lead smelting by the Huntington-Heberlein, Salvensberg and Carmichael-Brown processes and their followers," to which may be added the Dwight-Lloyd roasting furnace. "Note the renewed interest bestowed on the question of the purification of metals by means of forced oxidation. It is not too much to say that, without the precedent of the surpassing success of the pneumatic treatment applied to copper and iron sulphides, these promising departures from established tracks in other metals would have been delayed very many years."

In a second paper I shall tabulate the calorific value of the more common metals and sulphides and compare them with carbonaceous fuels, and will suggest a simple form of apparatus to experiment on the problem of burning them effectively.

Denver, Colo.

Faraday Society.—The program of the meeting of the Faraday Society, scheduled for March 27 in London, is a symposium of papers on "Optical Rotatory Power." Papers will be presented on this subject by H. Rupe, H. Grossmann, L. Tschugaeff, T. M. Lowry and T. W. Dickson, T. M. Lowry and H. H. Abram, R. H. Pickard and J. Kenyon, T. S. Patterson. Sessions are to be held in the afternoon and evening.

The Otto Coking Company, Inc., a corporation, has been formed to operate in the United States, and on March 1, 1914, has taken over the organization, assets and good will of the Schniewind Coke Oven Company, the United Coke and Gas Company, the German American Coke and Gas Company and the American Coke and Gas Construction Company. The Otto Coking Company is controlled by the interests in Dr. C. Otto & Company, of Dahlhausen a. d. Ruhr, Germany, and the Otto By-Product Coke Company, of Leeds, England. The object is to introduce into the United States the Otto Regenerative By-Product Coke Oven, with direct recovery of ammonia, tar and benzol. The new company starts out with a contract for the immediate erection of a plant for the Buffalo By-Product Coke Corporation at Lackawanna, New York, near Buffalo, with several other negotiations now going on for additional plants. The permanent officers of the new corporation will be Dr. M. G. Christie, Leeds, England, President, who will spend about half his time in this country; Dr. C. Otto, Assistant to the President, who will shortly take up his permanent residence in this country, Dr. Otto being the son of the inventor of the original Otto oven. The Vice-President and General Manager will be Mr. Louis Wilputte, one of the best known coke-oven engineers in America. The Secretary and Treasurer will be George F. McKay. The temporary offices of the corporation will be at No. 6 Church Street, New York City, where they will occupy the entire seventh floor.

Metallic zinc production in the United States for 1913 was the greatest in the history of the country, according to the U. S. Geological Survey. Spelter from domestic ores amounted to 337,252 tons, and from foreign ores 9424 tons, making a total of 346,676 tons. This is a gain of 2.3 per cent over the output of 1912. Missouri led in production and Illinois in smelting.

¹Pyrite Smelting, p. 151.

²Bulletin No. 80, A. I. M. E., Aug., 1913, p. 2130.

³Bulletin No. 83, A. I. M. E., Nov., 1913.

Hygiene and the Use of Ozone for Ventilation*

BY PROF. CZAPLEWSKI

At the congress at Frankfurt, June 10, 1909, the use of ozone for ventilation was treated by W. Cramer. Today this subject is treated in detail by myself and by Mr. Cramer, and the reason for these two reports is that after a period of praise for ozone in ventilation there has succeeded a wave of disapproval and objection. It is only just that we go over the field and see what we can say for and against ozone. The following article gives the truths about ozone and its hygienic importance in purifying and improving the air and its use in artificial ventilation.

In nature ozone is found in the air after lightning and rains during a thunderstorm. The quantities of ozone are, as Wolpert shows, so small compared to those produced artificially as to have little importance hygienically. Davy claims that this quantity is 1 mg. in 100 cbm. air; Wolpert says it is impossible to determine accurately the small quantities of ozone formed in the air, as any ozone in the atmosphere is decomposed by organic matter and gaseous impurities. The air in inhabited places is poorer in ozone than in the country, and in closed rooms the air has no ozone at all. Houzeau, Fox and Wölffhügel all attest this. The ozone percentage increases with the height above the ground. The maximum percentage of ozone is found in May, the minimum in November.

It is believed that the impurities which arise from animals and man are destroyed in the air by ozone, which is thus used up. The hygienic quality of the ozone in the air thus is of a negative character, since the air becomes purer, not because of the presence of ozone, but because the ozone is utilized to oxidize the impurities and dust particles.

Investigations on the influences of ozone on disease bacteria were taken up successfully in 1891 by Fröhlich. The work done by Ohlmüller led to this conclusion: "The ozone has a destructive action on bacteria when the water is not too much contaminated with lifeless organic substances." Sonntag was not able to prove a bactericidal effect with dry ozone, nor did Konrich get very encouraging results. Filter paper, dipped in bouillon cultures and dried, was exposed to the ozone in a glass vessel without becoming sterilized. The same was true when the bacteria were dried on glass rods, thus bacteria are not killed by dry ozone. Better results were obtained when the ozone was used on wet filter paper. There were killed in glass vessels with simultaneous moistening by steam: after 1 hour, typhoid, para-typhoid B., dysenterie, Shiga-Kruse; after 2 hours, dysentery-Flexner; after 2 to 3 hours, Coli; after 3 hours, para-typhoid B. pyocyanus, prodigiosus, sarcina aurantiae, sarcina flava; after 4 hours, tetragenus; after 2 to 4 hours, staphylococcus aureus (not quite certain); after 4 hours, not yet: spores of anthrax and subtilis.

Bail says there is no question that ozone dissolved in water has a bactericidal effect of the highest order, and sometimes such an effect might exist in air ozonation, as in cold storage for meats.

Kuckuck states that in the Heidelberg public bath he reduced the air bacteria 50 per cent with ozone. Labbe noticed a great decrease in the germs in the room, even with the curtains and handings drawn.

We may assume that the tests so far have not given conclusive results regarding sterilizing effect of ozone in air. More favorable results have, however, been ob-

tained with actual ozone ventilation, especially in egg and meat cold storage plants. It is indisputable that the introduction of ozone into ventilation has resulted in better preservation of meat and prevention of moulds; the cut faces become hard and there is a saving because less of the surface cuts need be thrown away because of mould. There seems then to be an unmistakable antiseptic effect of ozone. In such operations we have, however, stronger ozone concentrations, and besides the bacteria do not grow as rapidly in the low storage temperature, are weaker, and there is the surface hardening which makes it more difficult for bacteria to procreate and thrive.

Effect of Ozone on Dust.—If ozonized air is passed through long glass tubes, it loses some ozone; the ozone is used for the oxidation of the organic contents in the tubes. This was found by Fox and Wolffhügel.

Effect of Ozone on Odors.—Erlandsen and Schwarz stated, basing their opinion on the fact that the odors reappeared, that it is a matter of covering odor, not removing odor, and that we deal with a similar case when decaying material or fecal matter is covered with carbolic acid, and the latter odor overcomes the former without destroying it.

The two opinions, destruction of odor and covering of odor, stand diametrically opposite to each other. Konrich goes, perhaps, farthest when he ascribes to ozone merely a perfuming effect.

Disposal of Odor.—Most chemical substances have some odor, and many are scents, often very powerful; some are simple, others complex. Among the simple scents are chlorine, bromine, hydrogen sulphide, iodoform, and among the more complex, merkaptane, indole, skatole, trimethylamine, etc. There are substances which do not themselves smell but which become odorous under the influence of heat or moisture, e.g.: trioxymethylene in itself is odorless, but when decomposed gives a strong, penetrating formaldehyde odor; hydrogen sulphide is produced by the decay and decomposition of sulphurous metals and alkalies.

In the disposal of odors we differentiate between odor distributed in the room, that can be removed by ventilation, and fixed odor, or odorous substances that cause odors and are, therefore, permanent sources, as, e.g., odor *fixed* on the surfaces of objects in the room. This depends on the *quality* of the surfaces, whether of porous or impervious materials. With smooth and impervious surfaces, as metal, glass, porcelain, stone, oil coatings, furniture polish, varnishes and lacquers, we must consider also their heat conductivity. When they cool there may be a deposit of moisture through condensation of water vapor, which occurs the more rapidly the greater their specific heat and conductivity coefficient.

With porous materials we must differentiate between porous and hygroscopic properties. The former absorb air and water vapor only into their pores, the latter absorb water vapor and with it, probably also, dissolved gaseous substances. When the temperature is lowered the air or water vapor enclosed in the pores contracts; when the temperature rises the volume increases and liberates the water vapor and the absorbed gases. This is important in connection with the appearance of obstinate after-odors. Of the hygroscopic substances, animal textures like wool, silk, hair, fur and less so the vegetable textures like cotton, linen, pure cellulose, absorb odors readily. The persistent odors which cling to clothing and hair after exposure to tobacco smoke often prove as disagreeable as does cold smoke itself.

We must deal, therefore, with simple absorption, in porous surfaces and also possibly with a chemical action as through hygroscopic surfaces. We must also con-

*A lecture held at the Ninth Congress for Heating and Ventilating at Cologne, 1913. Translated in abstract by Dr. M. W. Franklin.

sider the character and area of the surface, which depend a good deal on the surface development in the room. Odors will stick much longer to rough, porous walls whitewashed and coated with linseed paint, hangings, tapestries, upholstered furniture, because these absorb them, while smooth and impervious walls, smooth furniture, lack of hangings, etc., facilitate the removal of odors. We first dispose of the source of the odor, but this is difficult if we have walls saturated with odors as sources. Results might be obtained in this case by driving the odors out of the walls, by increasing the temperature and distilling them out and then treating the free odors with ozone.

Hiding or Covering of Odors.—In effective concentrations ozone can destroy certain odors through oxidation, as we can prove beyond a doubt for hydrogen sulphide, indole, skatole and decayed matter. If the odor appears after the ozone is removed the after-odor is due to the residues of the odors absorbed by the walls, carpets, furniture, upholstery, etc., and which were protected from the ozone by their depth. Of great importance for the explanation of after-odors are the experiments of Lehman and Kisskalt as to the absorption of scents. When Kisskalt brought dry ammonia vapor into a room so much was absorbed that even after two to three weeks several grams per day passed back into the air.

Tests to Remove Odors with Ozone.—Hill and Flack found ozone to be powerful in removing odors. They filled their test room with tobacco, ammonia sulphate, carbon disulphide vapors, human excrements or putrefied meat, and they were not able to discover the odor after two minutes of ozonation.

Erlandsen & Schwarz and L. Schwarz had no great success in their tests in large rooms, although the latter states that large quantities of ozone in truth deodorize the room. In general, scents and odorous substances, which are clearly defined chemically and simply constituted, as hydrogen sulphide, sulphur dioxide, ammonia, indole, skatole, iodoform, etc., are destroyed by ozone.

Ozone and Hydrogen Sulphide.—Kisskalt found hydrogen sulphide to be decomposed in the air, with ozone in excess. Erlandsen and Schwarz proved that ozone destroys the hydrogen sulphide odor.

Ozone and Sulphur Dioxide.—Schwarz and Münchmeyer showed that an excess of ozone would react with at least part of the SO₂ and form sulphuric acid.

Ozone and Indole, Skatole.—Erlandsen and Schwarz found indole and skatole odors greatly reduced and even absent. Kisskalt treated a room smelling stuffy and damp, and with whitewashed walls, with ozone, 0.37664 mg. per cbm. (= 0.1883 per million), and skatole was evaporated over a gas lamp. He concluded that the skatole odor had been destroyed by the ozone. Schwarz and Münchmeyer in quantitative tests found indole and skatole destroyed in a short time with an excess of ozone. In the control tests there was a strong skatole and indole odor, while with ozone there was an agreeable, etherlike odor.

Ozone and Merkaptane.—Schwarz and Münchmeyer found that merkaptane is easily oxidized by ozone.

Ozone and Trimethylamine.—Erlandsen and Schwarz could not destroy the trimethylamine odor with ozone, but they evaporated 5 cc. of a 33 per cent aqueous solution in a room with less than 15 cbm. contents.

Ozone and Butyric Acid.—The smell of butyric acid was removed after 70 minutes' action of ozone. After an hour the smell returned, however, and was present even on the next day. Kisskalt found that butyric acid vapors in the air had not combined chemically with the ozone after 50 minutes.

Ozone and Iodoform.—Tests of Dr. J. Muller in the Nuremberg City Hospital demonstrated that the smell of iodoform is removed by ozone.

Experiments of Bail.—Bail found that with ozone in the small quantities possible in ventilation the odor of evaporated decayed matter was strongly affected after removing the source of the smell. The nauseating character of the odor disappeared, leaving behind only a persistent glue odor. He noticed that the ozone smell always appeared later, while the air took on a peculiar "fresh" characteristic. (This coincides with the views of Cramer, Hill and Flack.) The later appearance of the ozone odor indicates that ozone is used for the oxidation of the odorous matter and can appear only after having removed this. The original smell is made of a number of individual odors, some of which oxidize and leave the glue odor behind. They did not reappear after stopping the ozone supply so that they must have been destroyed.

"We may conclude, therefore, that small quantities of ozone, practically used, can destroy certain disagreeable odors in the air, and there is no reason to doubt that the excrements and their odors can be influenced by ozone. Through this fact we could explain the excellent results obtained by Lübert and others with ozone in theatres, halls, etc."

Ozone and Tobacco Smoke.—Of greatest interest, on account of its application to restaurants, is the influence of ozone on tobacco. Cramer says: "If we blow ozone into a glass tube filled with tobacco smoke the smoke conglomerates and soon disappears."

Hill and Flack were able to dispose of tobacco smoke through ozone. Erlandsen and Schwarz saw no influence of ozone on very heavy tobacco smoke, though in weaker concentrations the smoke was "covered over" by the ozone. In our own tests with strong ozone concentrations, cigarette smoke was entirely destroyed in a room and could not be perceived after re-entering the room, as there was no after-smell. Tobacco smoke on clothing is disposed of by the ozone. Konrich says that ozone has only a perfuming action, without destroying the smelling substances, but it is impossible to substantiate his opinion in view of the exact tests of Kisskalt and of Schwarz and Münchmeyer.

Is Ozone Poisonous?—Much excitement has resulted from the cry that ozone is a poisonous gas. Hill and Flack, as also Konrich, have made a considerable stir in this direction and it is therefore necessary to go more fully into their work. All agree that weaker ozone concentrations have no harmful effect at all, while stronger concentrations produce more or less local irritation of the mucous membranes. Schultz believed that the ozone went directly into the blood and worked secondarily on the lungs. This opinion was disposed of by Bohr and Maar, who showed that the lobe of the lungs influenced by strong ozone became irritated, while the other half, treated with ordinary air, remained normal. Pflüger states that ozone in contact with blood is immediately destroyed. Cramer said at the Frankfurt Congress for Heating and Ventilating: "In earlier times we assigned to ozone a poisonous influence on animal organisms, while recent investigations have shown that the ozone is poisonous only when made chemically and not pure. A mixture of chemically pure ozone with atmospheric air can, if the percentage of ozone is not too concentrated, never hurt an organism, as statements from doctors and scientists show. Only in very concentrated form does it attack the lining of the mucous membrane."

Hill and Flack state that the only action of ozone is that it causes irritation of the lungs if inhaled in strong concentrations for a considerable time, and that the danger signals are well set. These authors report tests with rats, cats, dogs, goats and mice. The animals were placed in airtight glass chambers and the ozone varied between 2 to 40 parts per million. They conclude that

animals die when exposed to 15-20 millionths parts for two hours, but this does not coincide with their table wherein a dog and three rats recovered after exposure to this quantity. The causes of death were inflammation of the respiratory tracts, blood congestion in the lungs and edema of the lungs. Microscopically the alveolae showed inflammatory exudations and hemorrhages. There were no other changes in the body.

There are several objections to these tests. First, it is not certain that their accounts of the ozone concentrations were correct; they determined the ozone in acidic potassium iodide solution (1 per cent), and this gives too high ozone value; also their method of using only 10 liters of air in the determinations is questionable. The judgment of such animal tests as regards the poisonous quality of the ozone is moreover very difficult. There are no figures to show the size of the experimental chamber, the quantities of air passed, nor the circulation. With their tests on odor disposal they placed two ozonators at the ceiling of the experimental chamber, but in the animal tests these points are not mentioned. There are no indications of the capacity of the ozonators. Through all these omissions it is difficult to see whether the disturbances in the animals are due to the ozone alone, or whether other causes like insufficient ventilation, excess of heat and carbon dioxide poisoning are to be added, nor do we know that the authors did not use ozone free from nitric oxides, therefore we cannot regard these proofs very highly. Hill and Flack used enormous concentrations in their animal tests, which by far transcend the quantities ever used in practice, and yet they have not always led to death.

Animal Tests of Konrich.—Konrich used a glass chamber 44 cm. long and 20 cm. wide and 18 cm. high, equal to 15,140 ccm., and gives accurate results of his seven tests. The ozone was produced in a grate ozonator and passed into the chambers under special precautions. He used rabbits, guinea pigs, white rats and mice.

There are many objections that can be brought against these experiments. The animals were in a comparatively small space, in some tests too many animals were in the chamber (1 rabbit, 2 guinea pigs and 4 rats); the quantity of air was 13.5 to 73.62 liters per hour, which is very little. The change of air was therefore in one case less than one time per hour; three times, more than twice per hour, and twice, more than two times per hour. Only in the last tests were the changes more than 4.6 times per hour, but in this test the ozone concentration was very high (0.23 gms. per cbm.). These facts give rise to the opinion that they died through other influences than ozone, as CO₂ poisoning, excess of heat, etc., a good quantity of the 16 liters of air being used by the animals. It may be that there are other causes, as for example, nitric oxides or nitrous vapors, as seems possible from the appearance of the lungs. My conclusions on this last fact are based on experience I obtained in the poison cases, through nitrous vapors, in Cologne. My suspicions were further confirmed by Von Kupffer, who stated that it is possible for nitrous vapors to have been formed as Konrich did not cool his ozonator grate frequently.

That pure ozone is not dangerous to small animals was proved by Sigmund. Labb   and Oudin call attention to the fact that chemically prepared ozone is always impure and often has constituents like phosphorous acid. When we approach natural conditions in treating animals with a mixture of atmospheric air and ozone we find no harmful effect. Labb   says: "Among the numerous ozonators there are very few that can produce a pure ozone in quantities that have been determined to be correct by tests. Moreover, it is very important to avoid the production of nitrous products as otherwise there will be caused irritations."

Konrich's Tests with Human Subjects.—The experimental chamber of glass and wood with air-tight doors has 3.8 sbm. capacity. A grate ozonator and electric ventilator were used. Through special valves the changes could be made so as to stagnate the air, circulate it, ozonize, remove this air and change by fresh air, bring in partly used, partly fresh air; ozonized and circulated air; air removed and then filling the chamber with fresh air. In the chamber there were one or two persons who remained from 40 minutes to 4 hours 35 minutes. In the tests with stronger concentrations the ozone varied between 0.431 and 6.72 mg. per cbm. Through adding steam the air in the chamber could be saturated with moisture. In other tests the air was dried and in some cases heated.

Konrich calls attention to the fact that the tests with people give the same results as those with animals, only that the irritations of the respiratory organs are more in evidence, and he adds that the sensitiveness towards the ozone is very different individually. The mucous membrane seems to be more irritated when the air is dry; when the air is very moist the presence of ozone is less irritating, and it is not as perceptible as an odor. The subjects suffered considerable inconveniences and trouble physically, but it is questionable whether these were due to ozone or to the other causes.

This question, according to my opinion, must be answered negatively. The tests were made in an abnormally small space, usually without air renewal, only the room air being ozonized. That the air in the chamber was vitiated to the highest degree is not surprising, and this is shown by the high increase of carbon dioxide content. We may assume, moreover, that the CO₂ at the floor level was even worse; the temperature also was very high (21 to 25 deg. C.); the humidity varied between 60 per cent and 90 per cent. Konrich thought the dry air increased the irritability of the membranes to the ozone, so he humidified the air with steam.

We cannot very well call air of 66 per cent to 68 per cent, or even 60 per cent, relatively dry. Esmarch says that a room with 30 per cent to 60 per cent relative moisture is hygienically proper. The percentages above 60 are therefore high. In test (7) the humidity rises to 80 per cent and then to 100 per cent, then after 12 o'clock 13 per cent to 25 per cent steam is admitted, whereupon the ozone odor is reduced and the burning of the eyes, also the coughing, are decreased.

Why more steam was admitted is not clear, since there was enough moisture without this addition; at this time the temperature was 30 deg. C. at 80 per cent humidity. This is a tropical climate artificially produced, and it caused trouble through excess of heat and the high humidity factor and its influence on respiration and on evaporation from the skin. To this must be added the poisonous effect of the CO₂. The calcium chloride drying apparatus was able to reduce the moisture only to 55-66 per cent, which is still too moist; however, the temperature was relatively low (18 to 20.5), while in the other cases it was 25.5 deg. to 29 deg. C.

I am nowise inclined to state that ozone is not harmful when used in very strong concentrations, and that it then could not irritate. We know the intensive action of ozone from water sterilization and we can easily demonstrate its chemical action, but I do not think the phenomena in these tests are pure ozone effects, as there are many other factors that enter. Labb   and Oudin, moreover, noticed in the production of ozone the phenomena of metal vaporizations, and it is well known that metallic vapors have a strongly irritating action and are very poisonous.

Author's Tests.—I, personally, made some tests with ozone. Two systems were used, the one in the abattoir of M  hlhausen, using a large central ozone ventilating

plant with water cooling device, the other with two local ozone generators without cooling. Low concentrations were found pleasant whilst stronger concentrations of ozone caused more or less irritations. Several persons claimed that with stronger concentrations they felt tired, faint and had headaches. After longer exposure in the rooms with stronger ozone concentrations they felt, on the next day, physically tired, but in these cases there were used concentrations which could not be used practically even in the worst cases, one test showing 2.7 grams ozone and 1 cbm. air. No really serious disturbances were noticed, though several times it was possible to smell an after-odor of ozone absorbed by clothing.

Results from Practice.—The preceding results show that there are no valid grounds for considering ozone a poisonous gas and this opinion is strengthened by the results of wide experience and practice. These particular results are all the more important since in them the ozone is not dealt with *milligrams* but in *grams*. It cannot be denied, moreover, that many times workers are exposed to high doses of ozone without being hurt.

Erlwein says: "It is a fact at any rate that there have never been proven cases of sickness of a serious character due to breathing ozone air. Special attention is called to a large water sterilization plant operating for more than ten years, where the working force is constantly moving in an atmosphere which is many times more strongly mixed with ozone than is ever found in actual ozone ventilation installations. There has never been a case where these persons have been on sick leave due to the high ozone concentrations."

Use of Ozone for Ventilation.—We come now to the use of ozone in ventilation. The air in closed rooms vitiates:

(1) Through respiration of the lungs, the liberation of carbon dioxide, liberation of water vapor, increase of temperature, perspiration from the skin, liberation of various exhalations, scents, among them probably the fatty acids.

(2) Illumination vitiates the air through increase of temperature, liberation of CO₂ and of odors, as petroleum.

(3) The admixture of other odors, as odors of food, tobacco, etc.

In the main we deal with an increase of the humidity, the carbon dioxide percentage, a decrease of oxygen and the vitiation of the air with disagreeable, offensive odors. Especially bad is this in assembly halls, restaurants and steerage decks. This vitiation of air is not only unpleasant but dangerous, and leads to poor breathing and faulty nutrition and digestion. Sensitiveness to odors varies and cannot be taken as a good indicator of bad air, as we get used to the bad air and it is only when we step out into the fresh air and then return that we notice it in the room. The air of uninhabited rooms becomes stuffy and close, due to the exudations of the walls and objects in the room, owing to lack of ventilation.

Ozone for Ventilation of Human Habitations.—As we need the oxygen in the air for our life processes, and as we can use the same only in the pure, uncontaminated state from the outside, we must resort to the latter to supply our rooms with fresh air. The only safe method of obtaining this is an efficient ventilation installation, but since it is not always easy to obtain perfect ventilation, ozone has been used in many cases as a very helpful ally, and within a comparatively short time there have been installed a large number of ozone ventilation plants.

We differentiate between: (1) ventilation with ozonized fresh air, and (2) ozonation of the room air. The former is preferable from the hygienic standpoint.

The favorable effect of ozone in cafés, restaurants, theatres and halls has been highly lauded. The ventilation of the subways is also a success. Lübbert has had splendid results with one of the most difficult subjects, the ventilation of emigrant ships. With closed windows the ozonator was able to maintain a tolerable air condition, which, without the apparatus, was unbearable. Regarding these tests of Lübbert, Konrich states that there were no complaints as to irritations from ozone.

Ozone is also recommended for public baths, which have, in spite of ventilation, a peculiar odor, made up of a number of simpler odors. The exudations of the skin with their fatty acids, the smell of the soap, of the water, of the wet mats, the wet woodwork, the wet walls and objects, all add in bringing about this odor. Kuckuck, in Heidelberg, has succeeded in disposing of this smell with ozone, and the same has been done in Breslau. The bath smell is superseded by that of fresh bleached wash.

Erlwein states that in dissecting rooms it has been possible to decrease the odor of dead bodies considerably.

It is necessary in weaving and textile mills to have a high degree of humidity, which has a very injurious effect on the workers, for with high humidity and temperature, evaporation and radiation from the skin are lessened and the body is unable to cool properly, and there results fatigue and reduced efficiency. Considerations of cost forced certain plants to work in the winter with recirculated air, which of course was partly vitiated, and, although again purified, it was unable to substitute for all the good characteristics of fresh air. Great success was attained when ozone was added to the fresh air.

Ozone in Industrial Plants.—A great field for ozone ventilation is open in the food industry, especially in the cold storage chambers of abattoirs. Ozone has caused direct saving in such plants, since the meat remains fresh and good for a longer time. In egg cold storage the ozone has given excellent results in that the disagreeable straw and box odor disappears, fewer eggs decay and the eggs last longer. The manager of the Cologne abattoir says: "Meat that had gone over into partial decay was to a certain degree recovered when the ozonator worked, and the mould coating disappeared."

Konrich reports on an ozonator plant in the Berlin abattoir, in the entrail cleaning room: "In this plant they were proud to state that the complaints of the neighborhood as to the stench from this part of the plant had disappeared. The same plant is also meant by Erlwein in his favorable report on an abattoir. Ventilation, as also an attempt to remove the odor by means of coke filter beds, were failures. The remedy was found when the gases rising through the chimneys were first passed through a duct with concentrated ozone. There is no trace of the former intensive odors. The expensive ventilation was removed and the plant was reported to be in perfect shape by the inspection department."

I might add to this that in the local city there is an abattoir with such a department and that one-half of the same works with ozonator, the other half without. A visit to both sides will easily permit the proper conclusions to be drawn. Konrich reports an ozonator plant in a herring packing establishment, where the success lay in the prevention of mould formation in the store room.

Vetter found that in breweries ozone could be used to purify bottles, barrels, to clean pipe lines and apparatus, after preceding mechanical cleaning. Filter cloths and yeast bags that could not be sterilized by means of steaming and boiling, were sterilized by exposing them for one hour to the ozone.

Quantity of Ozone.—The question of ozone concentration is a very important one.

Lack of Standard Method of Ozone Determination.—In looking through the literature the author was surprised to see the lack of uniformity in determining ozone quantitatively and found himself unable to draw valid conclusions from different tests or to compare them properly because of the variety of procedures employed.

For quantitative determination the KI method is usually used. A review of the different methods shows that there is no uniform determination. A uniform method is absolutely necessary, for the practical results of an ozone plant depend on proper concentration. A standard method should give detailed directions as to absorption liquid, concentration, reaction, quantity relations, form and size of measuring instruments, manner and length of passage of air, titration, etc. As the creation of such a standard method seems to me to be the *first fundamental requirement for scientific and proper advancement in ozone problems*, I would advocate starting a prize contest for the best and most accurate method of ozone determination which can be adopted as standard. A standard method of determination should be so delicate as to detect even the minutest quantity of ozone for whose determination we are at present restricted to the senses which are at best inaccurate. The ideal would be a method which would accomplish this with even a small quantity of air as 10 to 50 liters and give the results in a few minutes.

When Are We to Ozonize?—Konrich says: "We cannot answer this question in a general way. If the ozone is sent to the rooms through a central ventilating plant, weak concentrations can be used during the performance in the case of a theatre."

Personally I would like to add to this that we can expect successful results only if we use the ozone ventilation plant frequently, until the walls of the room are saturated with this fresh ozonized air. In inhabited rooms we can ozonize only in weak concentrations, but with uninhabited rooms there is no reason why we cannot use stronger concentrations, using them either before or after occupation, or both.

Value of Ozonation of Air.—Director Gutman, Stuttgart says: "It is not sufficient by any means, as has often been tried, to send ozone to a room regardless of its distribution, for then we usually have an over-ozonation of some rooms and an under-ozonation of others. This is clear when we recollect that we merely want to purify the air and require, therefore, only a certain quantity of ozone at any one point in the room. To bring in more ozone is useless and in excess cases even disagreeable."

Conclusion.—We may sum up all the points considered in the following way:

(1) Ozone is an intensely active gas. Its effect depends on its high power of oxidation. It acts more powerfully wet than dry. Energetic effects are obtained in high concentrations only.

(2) As regards the air purifying properties claimed for the gas we have: (a) We need not count on a destruction of bacteria in the air by ozone, nor their destruction on the walls of rooms, nor on objects in the room. (b) There is no oxidation of the organic dust particles. (c) There is, however, a positive effect on certain scents and the odors given off by the same. Some odors are destroyed, others are weakened. At times we obtain disagreeable mixed odors. After-odors are to be referred back in part at least to the odors absorbed by walls and objects in the room and later diffused outward.

(3) The effects of ozone on man depend on the con-

centration. In small and weak concentrations the effects are agreeable and are found to be refreshing and entirely without danger. In stronger concentrations the ozone irritates the mucous membranes and especially the respiratory tracts. The sensitiveness differs and is often increased through inflammation of the mucous membrane.

(4) Whether the cases of death in animals and sickening effects in man are due to the ozone alone is a matter of doubt. Care should be taken at least to see that the ozone is pure and has no nitric oxides and nitrous acid.

(5) In ozonation of air we must differentiate between (a) ventilation with ozonized fresh air (best central ventilation); (b) ozonation of enclosed room air. The former is preferable without question, and is the only one that need be considered in the development of the ozone ventilator problem. Ozonation of room air is often only a makeshift of dubious value. Tests with ozonation of room air allow no very valid conclusions which might be applied to the ventilation of rooms using ozonized fresh air.

(6) For ventilation with people in the rooms only the weakest concentrations are to be used, such as lead to no complaints by the people.

(7) Strong concentrations are to be used only when no persons are in the rooms, or in rooms used only for a short time. They are possible for industrial plants (although here temporary high concentrations may be used without danger or permanent injury).

(8) On no account does ozonation permit the curtailing of ventilation. Good ventilation is the first prerequisite. Ventilation can be improved by combining it with ozonation.

(9) With these suppositions and under these conditions, the use of ozone in the air seems not only permissible but even advantageous, especially in industrial operations and plants.

(10) The peculiar contradictions between the favorable practical results and the results of many laboratory experiments should be cleared up by further research.

(11) For this we need in the first place a standard method of ozone determination.

(12) A standard nomenclature for the ozone concentration is also desirable.

Prizes for Highway Study.—To encourage investigation of methods and materials for road and street construction, and to interest engineering students in highway problems, The Barber Asphalt Paving Company of Philadelphia, Pa., has offered prizes of \$100 for the best paper written by a member of the graduating classes of the leading engineering schools. The title suggested is "Asphaltic Materials for Highway Construction." The paper and its conclusions may be based upon service tests and the lessons of experience; the physical qualities or chemistry of asphalt; or it may combine any two of these lines of investigation. The length of the paper is limited to 3,000 words and all manuscripts must be received not later than June 1, 1914. The purpose of this prize offer is to turn the attention of engineering students to street and road construction as a field of work in which there is great need and great opportunity for trained men.

The Bunker Hill & Sullivan Mining Co. is having "moving pictures" made of all its operations in mining and milling. Underground operations will be photographed by the aid of a powerful electric light. The completed pictures will show the treatment of the ore by concentration from crushing to shipment of concentrates. It is reported that the films will be placed at the disposal of mining schools.

The Iron and Steel Market

The iron and steel markets became more and more quiet during March, until at the close of the month a state bordering on stagnation was reached. Strictly new buying became almost nil, and by the middle of the month specifications on contracts had dropped to 50 or 60 per cent of the rate obtaining in February.

The rate of steel production has not been decreased as a result of the smaller flow of shipping orders, and remains, as an average of the whole industry, at between 70 and 75 per cent of capacity, but there is no question that production will very soon have to be curtailed if demand does not improve. In some lines the mills have orders on books sufficient to enable them to maintain the pace of production for a month or longer, and the tin plate mills are still more strongly fortified, but in some lines a curtailment in output early in April is rather probable.

The steel trade has been at a loss to account for the loss in market activity in March. The lull in new buying which developed in February was expected, after the fairly heavy January buying, but a decisive improvement was fully expected before the close of March in anticipation of spring and the resumption of outdoor work on a large scale. A part of the quietness has been attributed to general timidity in business circles on account of legislative uncertainties at Washington in connection with the anti-trust bills, while a part is ascribed to a waiting attitude on the part of the railroads, due to the pendency of their demand before the Interstate Commerce Commission for an advance in freight rates. While these theories early found general acceptance, it has since become evident that some other influence must also be at work, for even in the midst of these conditions there should be more buying than has occurred during the second half of March, and there is reason to suspect that this other influence is that many buyers have adopted a theory that steel prices are going to be lower before they are higher. There are some good grounds for such a theory. Prices were advanced rather generally at the beginning of February, on the basis of the buying which had occurred in January, and to support such advances further good buying would naturally be required, and such buying has not occurred. In addition there is the condition that many contracts were written for the second quarter at \$1 a ton advance over first quarter prices. To make such contracts enforceable the general market would have to advance, and when it does not the result is that the business will have to be written over again. With a fresh period of competition for this business the whole price question would be reopened.

While steel prices did not definitely decline in March to any extent, there was softening in the case of several products, and plates and shapes became quotable at \$1 a ton lower than at the close of February.

Pig Iron

The market has become extremely quiet in all districts. In some cases furnaces have attempted to advance prices, but the advanced quotations must be recognized as purely nominal, since buyers evince no tendency to take hold. Indeed, there is the development that shipments against contracts are in some cases not being taken at the full rate. A few merchant furnaces are understood to be considering the question of blowing out in the near future, as soon as enough iron has been accumulated to take care of contracts now on books. Inasmuch as the merchant furnaces as a whole have not increased their production since the first of the year, while the steel interests have largely increased their pig-iron output, the country's requirements in

merchant pig iron must be quite limited. The market stands quotable as follows: No. 2 foundry, f.o.b. Birmingham, \$10.75; No. 2 foundry, delivered Philadelphia, \$15 to \$15.25; No. 2 foundry, f.o.b. furnace, Buffalo, \$13.25 to \$13.75; No. 2 foundry, delivered Cleveland, \$13.75; No. 2 foundry, f.o.b. Chicago furnaces, \$14.25; at Valley furnaces (90 cents higher delivered Pittsburgh), Bessemer, \$14.25; basic, \$13; No. 2 foundry and malleable, \$13.25; gray forge, \$12.75. Ferromanganese is nominally quoted at \$39, Baltimore, but the price on both prompt and contract can usually be cut to \$38.

Steel

The market in billets and sheet bars has been practically stagnant. When the mills advanced prices about the beginning of February their new quoting level was \$21 for first quarter delivery and \$22 for second quarter delivery on billets, with \$1 extra for sheet bars. Thus the market should really advance \$1 a ton on April 1, but conditions in the general trade hardly support an advance at this time. The sheet mills are indisposed to pay an advance as their market has tended to weakness rather than to strength during March. There has been no important inquiry to test the quotation for second quarter. Rods are \$26 to \$27, Pittsburgh.

Finished Steel

Prices named below are f.o.b. Pittsburgh, unless otherwise stated:

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.15c. to 1.20c.

Shapes, 1.20c. to 1.25c.

Steel bars, 1.20c., base.

Iron bars, 1.35c., Pittsburgh; 1.27½c. to 1.32½c., Philadelphia; 1.15c. to 1.17½c., Chicago.

Wire nails, \$1.60 per keg, base; plain wire, 1.40c., base.

Sheets, blue annealed, 10 gage, 1.40c.; black, 28 gage, 1.95c.; galvanized, 28 gage, 2.95c.; painted corrugated, 28 gage, 2.15c.; galvanized corrugated, 28 gage, 3.00c.

Merchant steel pipe, ¾ to 3 in., 79½ per cent off list.

Steel boiler tubes, 3½ to 4½ in., 71 per cent off list.

Standard railroad spikes, 1.45c., Pittsburgh; 1.50c., Chicago.

Structural rivets, 1.70c.; boiler rivets, 1.80c.

Cold rolled shafting, 64 per cent off list.

The Non-Ferrous Metal Market

Dullness characterized the non-ferrous metal markets during March. Buyers held aloof generally, seeming to be well covered for immediate needs. Prices quoted were not adhered to strictly, and producers were willing to make concessions to get business. On account of the accumulation of stocks, producers have exerted some pressure to sell.

Copper.—Business in Lake copper is in the hands of but one or two producers, and they continue to get their asking price. Quotations are nominal, however, as the same conditions prevail that have obtained for some months past. Considerable business has been done in electrolytic, but at reduced prices. Domestic consumption has exceeded foreign. Electrolytic now stands at about 14.07.

Tin.—An almost entire absence of demand characterizes this market, and consumers are apparently well supplied. The prices are low and conditions are favorable for a buying movement. March tin is quoted at 37½ cents.

Lead.—The American Smelting & Refining Co. continues to ask 4 cents for lead, which is the New York

quotation. Business at St. Louis has been done at 3.90 cents, and quotations are given as 3.87½ to 3.92½ cents.

Spelter.—Prices are lower and a larger tonnage is reported sold. It has been supposed that accumulation of stocks in smelters' hands has caused them to reduce the price to a point that would attract business. St. Louis quotations are 5.10 to 5.12½ cents, and New York 5.25 to 5.27½ cents.

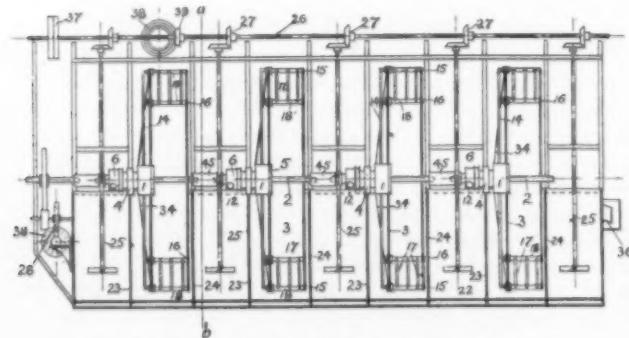
Other Metals.—The market for aluminium continues dull, with only moderate sales. No. 1 ingots are quoted at 18½ to 19 cents per pound, New York. Only a fair demand exists for antimony, and quotations vary from 6 to 7.35 cents for various brands. Business is good in quicksilver. The New York quotation is \$39 per flask of 75 lb. San Francisco price is \$38.50 per flask for domestic orders.

Recent Chemical and Metallurgical Patents

Gold and Silver

Slime Filter.—That all the possible modifications of continuous vacuum filters have not yet been considered is shown by the patent granted to Mr. James Drage, of Boulder, Western Australia. A four-stage machine is shown in longitudinal section in Fig. 1, and in transverse section in Fig. 2, the latter being on the line *ab* of Fig. 1. The object of the machine is to provide a series of filters, each with its agitating and filtering tank, for the successive washing of an ore pulp with several solutions or water washes. The filtering units proper are arranged in an annular ring around the periphery of a wheel. Each of the units is connected with sources of vacuum and pressure, so that as the wheel revolves the filter units that are submerged in slime pulp will be under pressure, thereby removing the liquid and forming a cake of solid on the filter fabric; on emerging from the pulp the units come under pressure so that the cake is discharged. Suitable means are provided to direct the discharged cake into the mixing and agitating tank of the next filter, where the same operation takes place, and so on through the four stages.

Referring to the cuts, the filter wheel is represented by 3, and the filtering units by 17. Pipes from each unit to the central valve connecting with vacuum and pressure are shown at 14. From left to right, each



lic bomb under vacuum. The reaction proceeds rapidly. On completion, the bomb is cooled and then opened in an atmosphere preferably free from oxygen and nitrogen. The mass is treated with water and then dilute acid to bring all calcium into solution. The insoluble residue is filtered and dried, preferably in a vacuum, at a temperature of 300 deg. or 400 deg. C. The product will be 96 per cent zirconium, about 3 per cent zirconium oxide and other impurities. The properties of the element thus prepared differ from those announced heretofore, and the inventors ascribe the difference to the fact that former investigators have not produced pure zirconium. (1,088,909, Mar. 3, 1914.)

Extracting Thoria from Monazite Sand.—The production of thoria in such condition as to be available for use in the preparation of the Welsbach mantle, is the object of a process patented by Mr. Charles Baserville, of New York City. The general composition of monazite is given in round numbers as follows:

P ₂ O ₅	29.0 per cent.
Ce ₂ O ₃ (earths)	31.0 " "
Di ₂ O ₃ (earths)	31.0 " "
SiO ₂	1.5 " "
ThO ₂	6.5 " "

The invention contemplates the reduction and volatilization of the phosphorus, and the simultaneous production of a silicon compound that is volatile at the temperature employed. There is the further object of incorporating in the mixture such elements as will permit the ready disintegration of the furnace product, when treated with water, thereby avoiding the necessity of expensive and difficult fine grinding.

For these purposes the inventor uses carbon and calcium fluoride, which, when fused with monazite sand in an electric furnace, will reduce and volatilize the phosphorus and form silicon tetrafluoride which

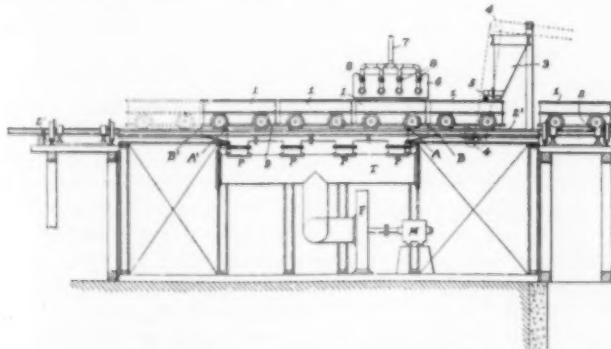


FIG. 3—SINTERING MACHINE

also is volatile. Further, the furnace mixture can be so compounded with lime that the production of calcium carbide will be formed throughout the mass, and when the latter is treated with water it disintegrates, yielding a product finely divided and not requiring expensive grinding. The furnace charge may be compounded thus:

	Pounds
Monazite sand	1.0
Carbon (petroleum coke).....	1.1
Quick-lime	0.8
Calcium fluoride.....	0.15

Various types of electric furnace have been used in producing the thoria, and both direct and alternating current can be employed of different voltages and amperages. The inventor prefers, however, to use a crucible furnace, also alternating current varying in amperage from 100 to 300 amperes and in voltage from 25 to 60 volts.

After the furnace product has been disintegrated by water, the lime is removed by decantation, and the residue is treated with acid to obtain a solution from which thoria can be extracted. (1,087,099, Feb. 17, 1914.)

Ore-Sintering Apparatus

A form of apparatus for sintering finely divided ores and similar materials, recently patented by Mr.

Albert F. Plock, of Pittsburgh, Pa., is shown diagrammatically in Fig. 3. In general, the process bears similarity to that of Dwight & Lloyd, wherein a comparatively thin bed of material is ignited and sintered while being passed over a receptacle from which air is being exhausted, thereby forcing a down draft through the bed of ore. Referring to the figure, cars 1, equipped with herringbone grates, receive a charge of material from the hopper 3, pass under the igniter 6, and across the air tank T. A motor M operates a fan F which exhausts the tank T, and thereby draws a current of air downward through the ore bed on the cars. The apparatus is designed to permit either continuous or intermittent operation, in accordance with the character and requirements of the charge; to permit the removal of the ore-carrying units to any distance from the sintering machine and to provide units which can be handled in any special manner desired. Each car has its own separate air chamber 14, as shown in Fig. 4 which illustrates a vertical cross section of the apparatus through the ignition hood. Fig. 2 also shows the manner of connecting the air chamber of the car with the chamber T that connects with the exhaust fan. This form of connection may be modified by placing it at one side of the car, or it may lead from the bottom of the car outside the wheels instead of between them. (1,089,153, Mar. 3, 1914.)

Another form of sintering apparatus is that of Mr. John E. Greenawalt, of Denver, Col., shown in Fig. 5. It consists, in brief, of a sintering pan 1 adapted to

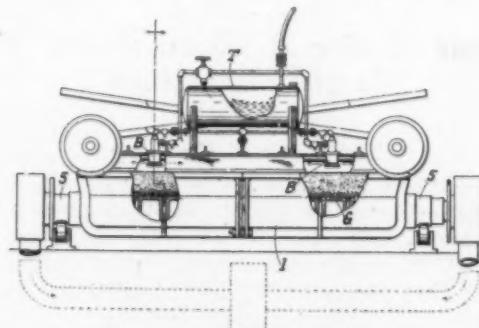


FIG. 5—SINTERING APPARATUS

turn on hollow trunnions 5. It is provided with a grate G on which a charge of ore is placed. The ignition apparatus is run over the pan, and the ignition of the charge is effected from two burners B of special construction. The ignition apparatus consists of a

tank T of oil fuel, with suitable connections to a source of compressed air, on the one hand, and with the burners on the other. The roof of the ignition hood is perforated to permit a down-draft current of air to be drawn into a combustion chamber, through the ore and out by way of the trunnions. In such an apparatus, the uniform ignition of the areal surface of the charge is an important point, and in order to provide for this, a special form of burner is used, shown in Fig. 6, by means of which a horizontal blanket of flame is projected over the entire surface of ore. The burner consists of two parts, a and b, bolted together. Between the two parts is placed a metal disk with radial slots, as shown at S. Oil is injected through a Schutte-Koerting spray-nozzle 24, and air enters tangentially at 25. The mixture strikes the cone 19 and is diverted horizontally through the radial slots of the metal disk, and spreads equally over the surface of the charge, forming a sheet of inflammable particles which, when ignited, produces a blanket of flame igniting instantaneously the entire surface of the charge. The projection of the horizontal streams of fuel is under sufficient head to suffer no material deflection by the downdraft current of air passing through the charge. (1,088,818, Mar. 3, 1914.)

Briquetting

The preliminary treatment of mineral and metallic substances which are to be united by pressure is the subject of a patent granted to Arpad Ronay, of Berlin, Germany. "The essential feature of this invention is that hot steam shall be introduced into the mass of particles to be pressed, at that period of time which precedes the pressing operation." The process may be applied to the briquetting of flue dust, ores, coal dust, metal filings or shavings and combination of such materials. The use of steam permits the displacement of air in the mass, and also introduces a small quantity of water which is of advantage. The desirable oxidation of the particles is brought about uniformly and quickly at the high temperature of the operation.

It is essential that steam, as such, exists in the mass at the time of briquetting. (1,087,183, Feb. 17, 1914.)

Synopsis of Recent Chemical and Metallurgical Literature

The Work of Crushing

In a mathematical discussion of the work done in crushing rock and ore, and the methods of finding the mechanical efficiencies of crushing machines, Mr. Arthur F. Taggart concludes that Kick's law is correct and that the so-called law of Rittinger is inapplicable.

The discussion appears in the January issue of the "Bulletin" of the American Institute of Mining Engineers. According to the author the reason why different investigators have arrived at different conclusions regarding the power consumed in crushing and the efficiencies of different machines, is that the tests are based on different assumptions. Some assume the correctness of Rittinger's law, that the work

of crushing is proportional to the reduction in diameter or to the new area produced, while others base their work on Kick's law, which states that the work of crushing is proportional to the volumes produced. After analyzing the proofs of various experimenters, the author comes to the conclusion that Kick's law is correct within the limits of experimental error.

"Attempts to prove the work of crushing proportional to the reduction in diameter err in one of the following ways:

"1. By neglecting the distance quantity in the work formula.

"2. By assuming that particles in a crushing machine are acted upon in such a way as to produce simple shearing stresses.

"3. By assuming that the force exerted is a constant.

"4. By confusing 'force' and 'work.'

"The difference in the results obtained according to the two assumptions is small throughout a considerable range of sizes. The difference is marked in the fine sizes, where the greatest amount of power is wasted."

Tin Concentration at the Geevor Mill, Cornwall.—The Cornish practice in tin dressing has frequently come in for more or less criticism from those who consider the methods inefficient and not in accord with modern ideas. On the other hand Cornish operators are likely to feel that much of the criticism comes from men unfamiliar with local conditions, and therefore unqualified to speak with authority. Bulletin No. 110, Inst. of Min. & Met., contains the record of an application of modern ideas of ore dressing at the Geevor tin mill, written by Mr. Horace G. Nichols. Bulletin No. 111 contains the extended discussion aroused by Mr. Nichols' paper.

It appears that the Geevor mill was remodeled under the technical direction and responsibility of Mr. R. Gilman Brown, and that Mr. Nichols was Mr. Brown's representative in the matter of starting the mill and gathering technical results. Unfortunately, and for reasons that do not appear fully in the discussion, the remodeled mill was unsatisfactory to the directors of the company, and it was changed back to conform with the method adopted at Dolcoath. This led Mr. Nichols to make public record of the performance of the remodeled mill in order to justify the methods adopted as compared with those in vogue before the change.

The principal feature of the remodeled mill is an attempt to introduce the principles of stage crushing, classification and concentration; adapting the crushing to the requirements of the ore, removing coarse mineral as soon as possible, and regrinding only such parts of the pulp as needed further treatment. The introduction of the Hardinge mill, Richards-Janney classifier and Deister table were "modern" features of the new mill. The use of vanners as coarse concentrators will appear strange and unusual to some, but these machines were in the old mill, and it was desired to use them as far as possible. The difficulty of remodeling an old mill to conform exactly with one's ideas will be readily appreciated by all engineers.

Mr. Nichols states that the recovery under the old practice was only about 40 per cent, and that the tailing contained 19 lb. "black tin" (about 2/3 metal) per ton. He admitted that a higher recovery, possibly 60 per cent, could be made under former conditions, but only by production of a low-grade concentrate. With the new system of treatment the yield was over 75 per cent.

The final treatment, arrived at by much testing, was as follows: From the stamps, which delivered a pulp containing about 35 per cent + 80 mesh material, the

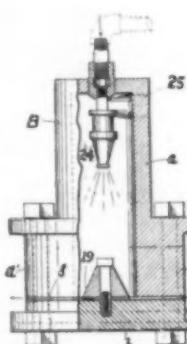


FIG. 6—BURNER FOR
SINTERING APPARATUS

ore flowed to a 3-compartment Richards-Janney classifier. The first spigot product, representing +80 mesh pulp, flowed to a Hardinge mill for regrinding; the second and third spigot products were treated on two sets of vanners, three machines in each set. The first set of vanners had a belt travel of 3 ft. per min., and were dropped 5½ in. at the tail end; the second set had a belt speed of 2½ ft. per min., and a tail drop of 4½ in. The overflow from the classifier was thickened in Callow cones, the thick product being treated on vanners which were run as nearly level as possible and speeded so as to obtain a not too clean concentrate. The tailings from the first two sets of vanners were reground in grinding pans and combined with the tailing from the third set. This pulp was then again classified in a 2-compartment classifier and concentrated on Deister tables. The finest pulp was ultimately thickened and treated on Deister slime concentrators.

The feed to the tube mill contained 62 per cent solids. This thick feed was regarded by the author as an essential requirement for regrinding tin ore. In concentrating with and without the use of a tube mill for regrinding a part of the ore, in the latter case depending on the stamps to grind the whole product fine enough, the percentages of extraction were respectively 78.5 and 69.5. Cone dewaterers were used over grinding pans, thereby eliminating much water and pulp finer than 120 mesh, and increasing the solids in the pan feed from 23 per cent. to 42 per cent. The author concludes from the results obtained that the principles of concentration adopted in treating other ores are equally applicable in tin ores.

Gold and Silver

The Cyanide Process.—A chemical and historical review of the metallurgical process which to-day holds first place as a means of recovering gold and silver from their ores is given by Mr. C. A. Mulholland in the Australian Mining Standard, Jan. 8, 15 and 22, 1914. Concerning the theory of the dissolution of gold in a cyanide solution, the author affirms that gold goes into solution in an indirect fashion, to form gold-potassium cyanide.

"Chemical energy is electrical energy. This dissolution of metals and their compounds and all reactions in solution take place by an interchange of electrical charges which are inherent in all kinds of matter. In a solution whose equilibrium is balanced the atoms and molecules with their definite electrical charges are also in equilibrium. Atoms or molecules going into solution—becoming ions—receive an electrical charge or become ionized, and as soon as they are caused to give up their charges they cease to be ions and separate out of the solution in the neutral or molecular state. In order that a metal can enter into solution it must be capable of withdrawing the charges for its own ions from those of others—for instance, from hydrogen or other metallic ions already present in the solution and the ion from which a charge has been taken separates in the neutral state. Applying this to the particular case of gold entering into a solution of cyanide its modus solvendi may be briefly described as follows:

"The electrolytic pressure of gold in presence of a cyanide solution (that is the difference between its solution pressure and the osmotic pressure of the ions in solution) is just sufficient to enable it to take up an ionising charge of low value from the potassium ions in solution to form an aurous ion which unites with hydroxyl to form a hydrate or more probably hydrated peroxide, which is readily soluble in potassium cyanide.

"The efficient initial cause of the dissolution of gold in a cyanide solution appears to be an electrochemical one, involving, primarily, the elements gold and oxygen. The slight apparent solubility of gold in cyanogen, cyanogen bromide and similar compounds is due to a similar cause and not to the nascent cyanogen molecule."

Another important contributing cause is the phenomenon of catalysis. Among catalytic substances acting in the cyanide process are the silica and ferrie oxide invariably associated with the ore under treatment.

A third contributing cause of dissolution is the state of dilution of the solution. When the dissociation of potassium cyanide in any solution has the greatest concentration of ions in unit volume, this point corresponds, within certain limits, with the solvent power of the solution.

A fourth contributing cause is the property possessed by potassium cyanide of dissolving with the absorption of heat, so that the dissociation pressure increases with the increase of temperature, within certain limits. This property influences the whole process by which substances enter the solution and determines their order and the direction of displacement of the equilibrium of the reacting bodies, however numerous they may be. The temperature, therefore, of the cyanide solution is another contributing factor in the dissolution of gold and other metals."

The author applies these considerations to the reactions occurring in the cyanide and bromocyanide processes, and concludes with a historical review of the patents.

Notes on Chemistry and Metallurgy in Great Britain

(From Our Special Correspondent.)

Rail Steels for Electric Railways

At a meeting of the Institution of Civil Engineers on February 24th Mr. Wm. Wilcox read a paper in which he described the results of tests which he had made bearing on the reduction of the life of rails in tunnels from an average of about five years to an average of rather less than three years, and in some places below one year, on the electrified section of the Metropolitan Railway.

The tests were mainly confined to the curve between Aldersgate and Farringdon Street, and were made with a great variety of steel rails. The traffic at this particular part of the line is exceptionally heavy and at busy times in the morning and evening there are more than 40 trains running in the hour on one line.

The author's investigation has been of an extensive character, and included chemical analyses, tensile tests, tup tests, and impressions of all the rails experimented upon as well as the etching of a large number of sections of the rails. In addition to the results of these tests the results obtained with various steels, including manganese steel, for actual wear at points and crossings are given.

The author points out the necessity for railways keeping their expenditure on permanent ways within a reasonable figure, especially when only about three hours can be devoted to the work of putting down fresh rails, which must necessarily be done after midnight and before the resumption of traffic in the morning.

In giving the good results obtained with manganese steel points and crossings on the curve mentioned, the author points out that, as far as he knows, the use of manganese steel in England, even at crossings, has

hitherto been very restricted, and that therefore these results may possess some value. Summing up the results obtained the author has arrived at the conclusion that the rails which have proved the best and most economical are of high-silicon steel manufactured under careful supervision by the process introduced by the late Mr. C. P. Sandberg from basic open-hearth, basic Bessemer and acid Bessemer steels.

The Effect of Alternating Currents on Primary Cells

At the mid-February meeting of the Royal Society Mr. S. G. Brown presented a very interesting paper on the effects produced by the passage of alternating currents of various frequencies up to a maximum of 20,000 through simple voltaic cells. The passage of an alternating current through any such cell appears to prevent entirely polarization, and as a consequence the chemical action becomes very much greater, and therefore the cells yield a much greater quantity of continuous current than they would normally supply.

When the surface of the zinc anode is relatively small the passage of an alternating current stimulates the chemical action between the electrolyte and the anode, and this causes a considerable increase in the current given out. Such increase is dependent in extent on the density of the alternating current, and the experiments described by the author go to show, if not to prove, that when the density is great enough the chemical action may be so intensified as to cause oxidation of any known metal used as the anode.

The Carbonization of Coal

Dr. John Harger recently read a paper before the Liverpool section of the Society of Chemical Industry in which he dealt with the chemical nature of coal and the products of its carbonization.

He said that the researches of many able workers for about a century had not resulted in the acquisition of any definite knowledge of the chemical composition of the substances of which coal was composed, and that with regard to 98 per cent of its constituents it was only possible to guess at their chemical composition. Some coals yielded 40 per cent of soluble matter to pyridine, and although part of this dissolved substance was soluble in chloroform yet it cannot be directly obtained from coal by treatment with chloroform; and this went to show that that portion of the pyridine extract which was soluble in chloroform did not exist in that form in the coal itself, but was formed by the action of the pyridine on some original constituent of the coal.

The government chemists at Eskmeals considered that the inflammability of any given coal is determined by the proportion soluble in pyridine, but he considered that that view was open to question.

The author reviewed the controversy between Dr. Wheeler and Professor Lewes concerning the processes of decomposition which occur when coal is heated, and he supported Professor Lewes in the view that the decomposition at the higher temperatures consists in a splitting up of pitch-like matters formed earlier at a lower temperature. In support of this he showed that at a temperature of about 270 degs. C. ordinary bituminous coal underwent a change not readily noticeable.

With regard to gas-works practice the author considered that modern methods should be revised, because he was of opinion that the existing practice of high temperature distillation is more suitable for the conditions of bygone times, and that the old method of working at lower temperatures was more suitable to modern requirements, such as a yield of light petroleum and smokeless fuel for ordinary consumption.

Rail Corrugation

At the meeting of the Institution of Civil Engineers on the 24th of February Mr. S. P. W. D. Sellon read a paper on "Rail Corrugation and its Causes."

He came to the conclusion that the "crests" are simply cold-rolled whilst the surfaces in the hollows are crushed by vertical loads, consequent on the oscillations of the wheels, above the elastic compressive limit of the steel; but he did not discuss the cause of the oscillatory character of the load. At ordinary speeds the pitch of the corrugations on tram rails corresponds with a frequency of about 100 per second.

The author was quite confident as to the means of prevention afforded by hard steel. He said that between 1898 and 1903 he was responsible for the purchase of 10,000 tons of tram rails with a specified carbon content of not less than 0.6 per cent which had been laid in various towns in England and had not exhibited any corrugation; but where the same tramways had been extended with rails complying with the British standard specifications and containing from 0.4 to 0.55 per cent. carbon corrugation had occurred on such extensions with the same rolling stock and the same method of construction.

Market Prices

February, 1914.

	£ s. d.
Aluminium ingots, ton lots	86. 0. 0
Alum, lump loose, ton	5.10. 0
Antimony, Star Regulus, ton	28. 0. 0
Borax, British refined crystal, cwt.	18. 6
Copper Sulphate, ton	22.10. 0
Caustic Soda, 70%, ton	10. 5. 0
Copper Ore, 10 to 25% unit	11/3 to 11. 9
Ebonite Rod, lb.	4. 6
Hydrochloric acid, cwt.	5. 0
India-rubber, Para, fine, lb.	3. 0
Mica, in original cases, medium	3/6 to 6. 0
Petroleum, Russian spot, gal.	9 1/4
Quicksilver (Spanish), bottle	7.10. 0
Sal-Ammoniac, cwt.	2. 2. 0
Sulphate of Ammonia, ton	12.12. 6
Sulphur, recovered, ton	5.10. 0
Shellac, cwt.	3.14. 0
Platinum, oz., nominal	9. 5. 0
Tin Ore, 70%, ton	113 to 115. 0. 0
Zinc, Vieille, Montagne	25.12. 6

Differences

Higher	Lower		
Copper ore, unit.....	3	Aluminium	4. 0. 0
Sulphate of Ammonia (ton)	2. 6	India Rubber	2 1/2
Tin Ore, ton	10. 0. 0	Shellac, cwt.	8. 0
Zinc, ton	12. 6	Copper, ton	1.12. 6
		Tin, ton	4.10. 0
		Lead, ton	10. 0

Copper opened £66, was £66.17.6 on the 4th, then declined to £65 on the 9th. It was a little higher on the 10th and 11th but again reached £65 on the 13th, and, after a slight recovery, £64.10.0 on the 18th, and has held about that price, closing at £64.7.6.

Tin opened £182 and rose till £187.10.0. was reached on the 4th: it then fell off, being £185 1/8 on the 9th, and £183.12.6 on the 12th; £183 on the 16th and £181 on the 17th, with fluctuations, the tendency has been generally lower, showing £175.15.0 on the 23rd and closes £175.10.0.

Haematite opened 61/- and has not varied throughout the month, closing the same.

Scotch Pig opened 56/, and was up to 57/9 by the 5th, keeping fairly strong till the 16th, when it was 57/: on the 17th, 18th and 23rd it was 56/9 and closes 56/6.

Cleveland opened 50/7 1/2 and rose, reaching 51/9 by the 5th, and was fairly strong till the 13th, when it was 51/1 1/2: it has since had a lower tendency, being 50/9 on the 18th and 23rd, and closes 50/6.

Lead opened £19.10.0, and rose to £20.10.0 on the 3rd: by the 9th it had fallen to £19.15.0 and remained there till the 11th, when £19.17.6 was reached, which has been maintained, closing price being £20.

Coal-Gas Plant and Lime Plant at the Niagara Works of the American Cyanamid Company

The production of calcium cyanamid represents one solution of the problem of the fixation of atmospheric nitrogen, that is, of the problem to transform the inert and useless elemental nitrogen in atmospheric air into some useful compound.

The calcium cyanamid industry is the result of the experiments of Drs. Frank and Caro, who wanted to produce calcium cyanide from calcium carbide and nitrogen by a reaction analogous to that by which

located at Niagara Falls, Ont., Canada, where electric power can be obtained at a sufficiently low rate.

The American Cyanamid Company owns the sole right to manufacture and sell cyanamid in America. Its factories at Niagara Falls began operations on January 1st, 1910. The original output was 12,000 tons a year, but this was increased during 1912 to approximately 32,000 tons a year, and further extensions are under way to give a yearly output of 64,000 tons.

From the very commencement of operations at Niagara Falls it was clear that a plant capable of producing 12,000 tons per year was totally unable to meet the market requirements, but the directors of the American Cyanamid Company adopted the policy that they

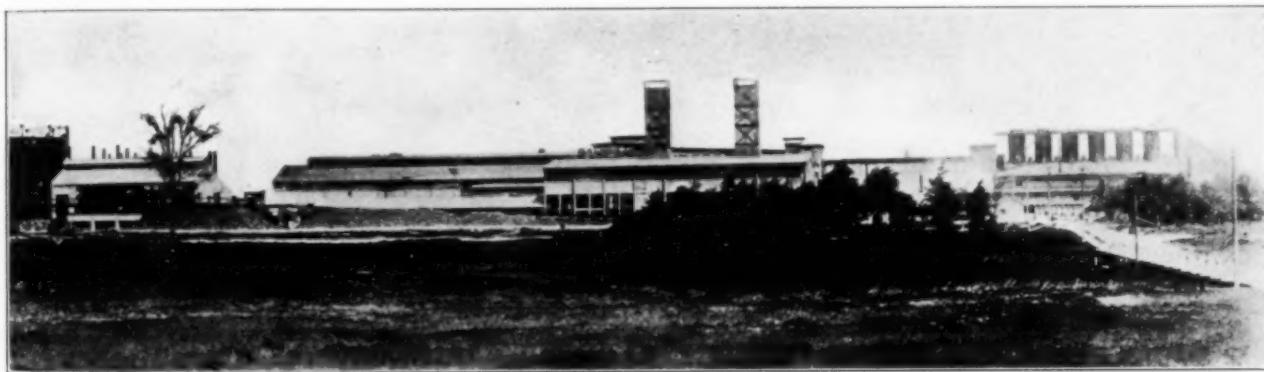


FIG. 1—AMERICAN CYANAMID COMPANY'S WORKS AT NIAGARA FALLS
(Lime plant at the extreme right and coal gas plant at the extreme left)

barium cyanide is formed from barium carbide and nitrogen. Their experiments showed, however, that in the cost of calcium the reaction is a different one since the calcium cyanamide instead of cyanide is formed. The inventors, however, found at the same time that the calcium cyanamide—which they had not originally intended to produce—was nevertheless a very valuable product as it can be used almost directly in the form produced as a fertilizer and may also be employed as a starting material for the production of other chemicals.

In the last ten years the production of calcium cyanamide has become a big industry. Its history has been given in the columns of this journal. Reference may be

would thoroughly prove the commercial practicability of and demand for cyanamid before building a large plant. After two years' experience they realized that the product could be looked upon as an undoubted commercial success. Methods of manufacture have been simplified and cheapened, and it is now necessary to double the

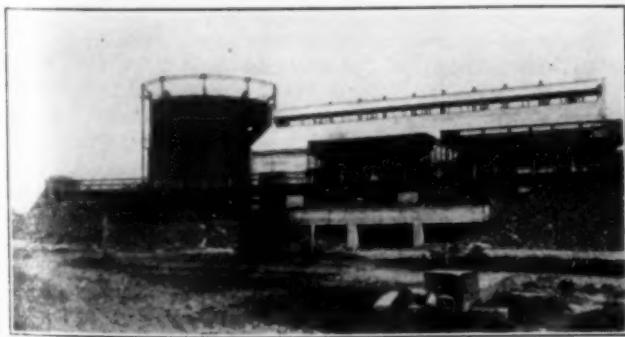


FIG. 2—RETOUR HOUSE AND COAL-HANDLING ARRANGEMENT FOR THE RETOUR HOUSE

had to former articles published in our volume I, page 423; vol. II, p. 204; vol. III, p. 28, 79, 117; vol. IV, p. 136, 188, 327; vol. V, p. 59, 72, 77, 98, 198, 289, 374, 464, 465, 479; Vol. VI, p. 139, 339, 341, 506; Vol. VII, p. 212, 305, 309, 360; vol. VIII, p. 47, 287, 539, 548, 589, 617, 682, 692; vol. IX, p. 12, 21, 100, 123, 476, 545; vol. X, p. 550, 551, 667; vol. XI, p. 438, 476.

In the last ten years cyanamid factories have been established all over the world. One of the largest is

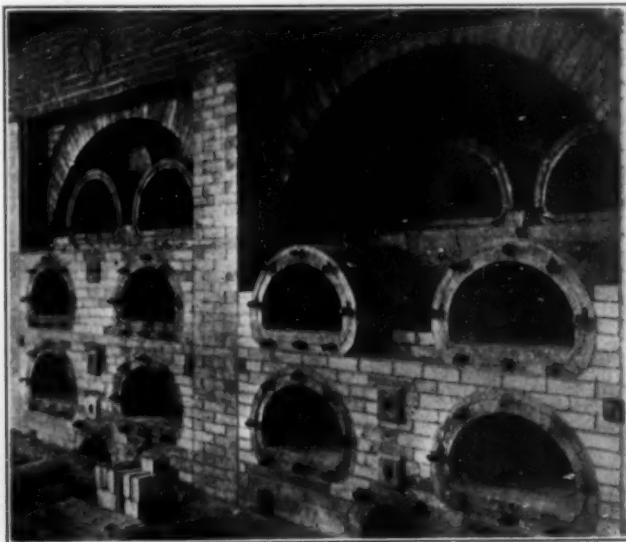


FIG. 3—MANNER OF LAYING UP THE SECTIONAL SILICA RETORTS AND SETTINGS

existing plant in order to cope with the increasing orders.

Cyanamid is a bluish-black, odorless, powdered material. It contains from 18 to 20 per cent ammonia, about 12 per cent carbon, or lamp-black, and the equivalent of about 70 pounds of slaked lime. The material is shipped in burlap bags and can be stored indefinitely.

Cyanamid nitrogen is readily soluble. Ninety-six per cent will dissolve out in cold water and is, there-

fcre, available as plant food. On contact with the soil it reacts quickly and changes finally into the form of double ammonium compounds.

Every 100 pounds of cyanamid contains the equivalent of about 70 pounds of slaked lime which adds considerably to its value as a fertilizer. This lime costs the



FIG. 4—CHARGING FLOOR OF RETORT HOUSE WITH CONVEYOR SYSTEM AND COAL BUGGY

farmer nothing, as cyanamid is sold on the basis of the ammonia it contains as determined by analysis.

Starting Materials of Cyanamid Manufacture!

Since calcium cyanamid is produced by the reaction of nitrogen gas with hot calcium carbide, and since calcium carbide is made in the electric furnace from lime and coke, the principal requirements of cyanamid manufacture are, besides cheap electric power, lime, coke, and nitrogen gas.

It should be emphasized that the nitrogen gas before being used must be separated from the oxygen gas with which it is mixed in atmospheric air. In some of the

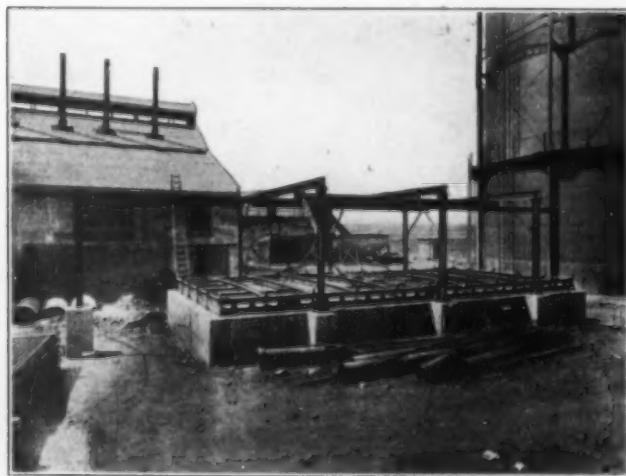


FIG. 5—PURIFYING BOXES

European cyanamid factories this is done by liquefying the atmospheric air and then separating the oxygen from the nitrogen by fractional distillation. At Niagara Falls another purely chemical and very simple method is employed. The atmospheric air is passed through a hot copper sponge whereby the oxygen in the air combines with the copper and leaves practically pure nitrogen. The copper oxide is then reduced again to copper

sponges in a second stage by means of coal gas as reducing agent. The reduced copper sponge reacts again with atmospheric air and produces nitrogen and so on. The copper sponge, therefore, undergoes cyclic oxidations and reductions.

The nitrogen ovens consist of a series of vertical retorts heated by small individual furnaces. Copper sponge is placed in these retorts, and when the retorts are brought to the proper temperature air is forced through the retorts and the oxygen of the air combines with the copper as cupric oxide, leaving the nitrogen free. This is the first stage. In the second stage the air is then shut off and coal gas is passed through the retort, which reduces the copper oxide to metallic copper. The nitrogen produced in the first stage is

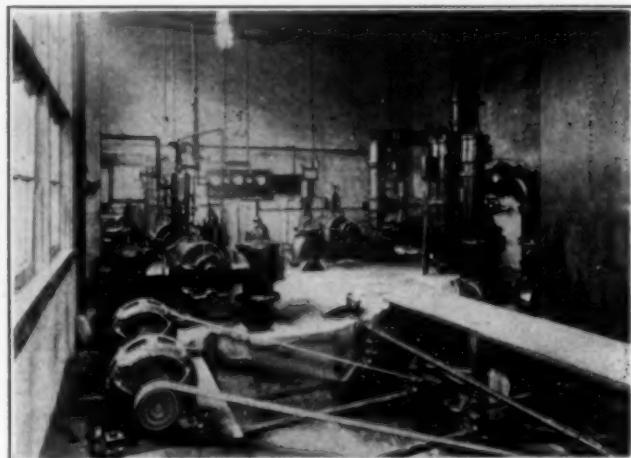


FIG. 6—MACHINERY ROOM WITH DOHERTY WASHER COOLER AND CENTRIFUGAL PUMP

forced through pipes into the electric furnaces where it combines with the calcium carbide and forms calcium cyanamid, or commercial cyanamid.

Coal Gas Plant

Since coal gas is used for the reduction of the copper oxide (in the production of the nitrogen gas) and since coke is used for the manufacture of the calcium carbide, a coal-gas plant is an important part of the factory, the coke going into the carbide factory and the coal gas into the cyanamid factory proper.

The coal-gas plant was designed and installed by the Improved Equipment Company of New York City, and has a capacity of approximately 500,000 cubic feet per twenty-four hours. There are seven benches of sizes equipped with the Doherty bench fuel economizer and sectional silica retorts and settings.

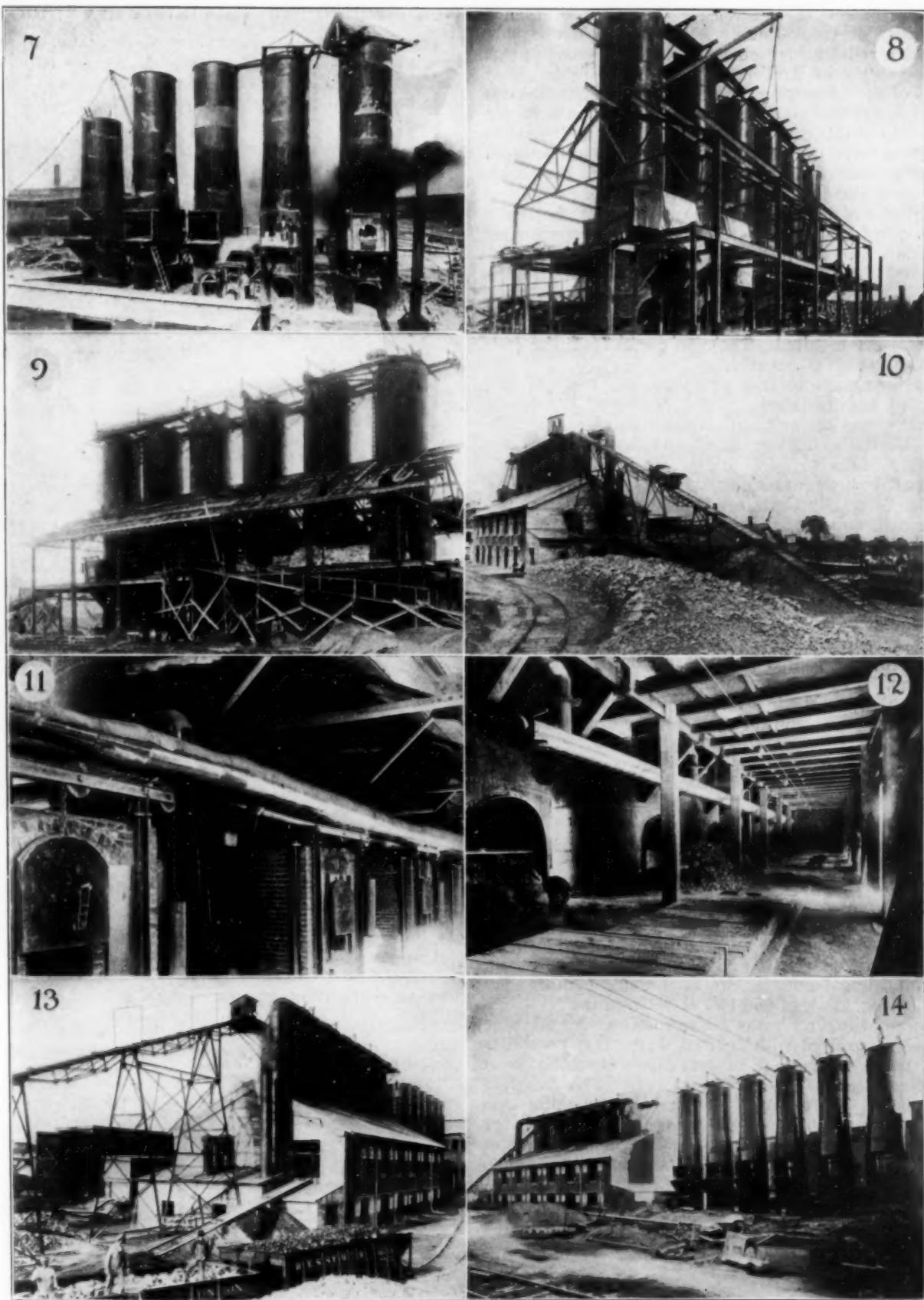
The accompanying illustrations give an idea of the principal features of this installation. The size of the whole plant can be seen in Fig. 1, with the lime plant at the extreme right and the coal gas plant at the extreme left.

Fig. 2 shows the retort house and holder and coal handling arrangements for the retort house.

Photographs were taken during the course of the installation of the plant, showing various stages in construction. Fig. 3, which shows the manner of laying up the sectional silica retorts and settings, should be of particular interest to gas men.

The view of the charging floor of the retort house (Fig. 4) shows the coke conveyor system and coal buggy.

The purifying boxes (Fig. 5) are of the concrete outdoor type. This view also shows the cooling coils of the Doherty washer cooler on the outside of the retort



FIGS. 7 TO 14—LIME PLANT IN COURSE OF CONSTRUCTION

Fig. 7—Kiln shells erected and fire-clay lining started; Fig. 8—kiln shells completed and section of waste gas piping installed; Fig. 9—work started on the roof of the lime-kiln building; Fig. 10—complete lime plant; Fig. 11—furnace or firing floor with piping for Eldred process and counterweight arrangement of the charging doors; Fig. 12—lime discharge floor; Fig. 13—old plant with new additions; Fig. 14—old plant with new additions.

house as well as the position of the holder which has a capacity of 100,000 cubic feet. This holder is only used as a relief holder when the nitrogen ovens do not use the output of the benches.

One of the interesting features of this installation has been the flexibility of the benches in that as a larger output is required the heats are raised and benches forced to meet the demand, or the heats are lowered when for some reason the nitrogen ovens are shut down or are not running to full capacity.

The view of the machinery room (Fig. 6) shows the Doherty washer cooler with centrifugal pumps for its operation.

Lime Plant

For the manufacture of the calcium carbide which represents the first step in cyanamid manufacture, coke and lime are required. The coke comes from the coal-gas plant which is described.

The lime plant for the production of lime was also designed and installed by the Improved Equipment Company, and the original plant consisted of six Doherty-Eldred lime kilns equipped with the Eldred process and induced draft.

Figs. 7 to 9 show this plant in course of construction. In Fig. 7 the kiln shells are being erected and the fire clay lining started; in Fig. 8 the kiln shells are completed and section of waste gas piping installed, and in Fig. 9 work is started on the roof of the lime-kiln buildings.

The complete plant is shown in Fig. 10 with the incline for conveying the limestone to the top of the kiln.

Fig. 11 shows the furnace or firing floor, showing the piping for the Eldred process and the counterweight arrangement of the charging doors, and the view of the lime discharge floor in Fig. 12 shows the arrangement for handling lime and the holes for the conveyor in the floor.

At the present time the lime plant is being doubled in size. Figs. 13 and 14 show the new addition as well as the old plant.

The New Heat Treating Department of the Ingersoll-Rand Company's plant at Phillipsburg, N. J., which was installed by Tate-Jones & Co., Inc., of Pittsburgh, is now completed and in successful operation. The plant at Phillipsburg handles a large output of drills and compressors and the furnace equipment in this department consisted of two large double-chamber annealing furnaces, two semi-muffle furnaces for pre-heating, six lead and two solution baths for hardening and three oil baths for tempering. All of these furnaces are fired with fuel oil which this plant has been using with great success since changing from gasoline gas in January of last year. The complete installation of furnaces, burners and pumping systems was made by the Tate-Jones Company and they now have in the two heat-treating departments at Phillipsburg forty-three and in the blacksmith shop four Tate-Jones furnaces.

Palace of Machinery at the Panama-Pacific Exposition.—If confirmation is needed of the often-repeated press assertion that the San Francisco World's Exposition will open complete on time on February 20, 1915, it seems to be found in the present finished condition of the Palace of Machinery. It covers a floor space of about eight acres; water, gas, electricity, compressed air, steam, overhead crane service are all provided in systematic and comprehensive detail. The installation of heavy machinery should begin at an early date and shipments which reach the exposition by July 1, 1914, may be expected to be immediately put in place.

New Metallurgical Laboratory in California

The new ore-testing laboratory of Mr. Charles Butters, at Oakland, Cal., is particularly designed for investigations in the treatment of refractory ores. Facilities have been provided for tests on any scale up to



FIG. 1—LEACHING TANKS, BUTTERS' METALLURGICAL LABORATORY

four or five tons, and suitable treatment can be determined for gold, silver or copper ores by any of the leaching processes in general use.

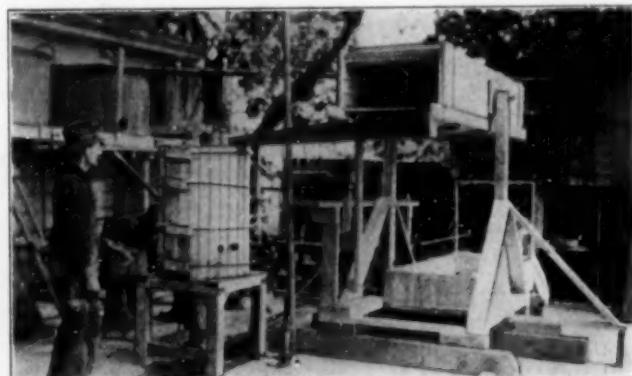


FIG. 2—VIEW OF BUTTERS' FILTER IN HORIZONTAL POSITION

The crushing appliances, which are all run by electric power, comprise two Grusonwerk ball mills, Gates gyratory crusher, Blake crusher, sample grinder and tube mills.

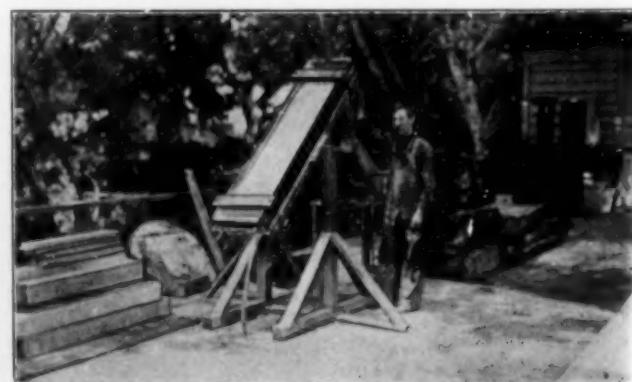


FIG. 3—FILTER IN INCLINED POSITION FOR DISCHARGING

Leaching and agitation tanks of various sizes have been erected. A general view of the leaching plant is given in Fig. 1. The agitation tanks comprise the reg-

ular mechanical type, Pachuca type and a form in which mechanical stirrers are combined with air-lifts.

The new type of Butters filter is shown in different views, Figs. 2 to 4. The details of this filter have been worked out at the testing laboratory. Fig. 2 shows the device in its horizontal position, ready to receive a charge of ore pulp. The apparatus consists of a number of superposed trays, each containing a filter mat of the regular type. These are charged simultaneously from a manifold that delivers pulp at one end of the apparatus. Fig. 3 shows the filter in an inclined position, ready to discharge. In Fig. 4 it is shown in the vertical position as it appears when the cake has been discharged.

Concentration tests can be made on the model Wilfley table shown in Fig. 4.

A zinc box of large capacity is provided for the re-

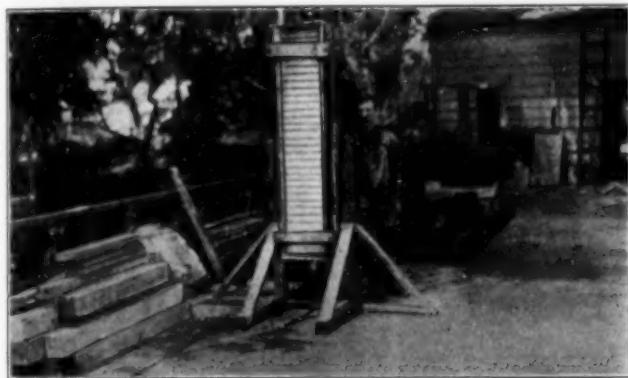


FIG. 4—FILTER IN VERTICAL POSITION, CAKE DISCHARGED

covery of valuable metals from cyanide solutions, and other systems of precipitation can be installed when necessary.

In addition to the experimental laboratory there is a well equipped assay office and analytical laboratory, the rooms used for this purpose being large and exceptionally well lighted, and furnished with every necessary appliance.

The entire installation is situated on the grounds of "Roselawn," Mr. Butters' Oakland residence. It is accessible both from Fifty-ninth Street and from Shafter Avenue, where the Oakland, Antioch and Eastern Railway affords a ready means of delivery. Rockridge station on this line immediately adjoins the plant.

The Goldfield Consolidated Mines Co. has declared a regular dividend of thirty cents per share, which will be payable on April 30 to stockholders of record on March 31.

Butte & Duluth copper costs for February are announced as 8½ cents per pound. The company is treating oxidized copper ore by leaching and electrolytic precipitation. The ore averages 2.11 per cent copper. The cost per ton of ore was: Sulphuric acid, \$0.72; electric power, \$0.375; mining and transportation, \$0.23; fuel, \$0.14; labor, \$1.029; total, \$2.494.

The Arizona Copper Co., Ltd., produced 1531 tons of copper during the month of February, 1914.

A short course in coal mining is announced by the Colorado School of Mines for the benefit of coal mine employees. The course lasts eight weeks, from April 1 to May 27. Elementary chemistry, geology, mathematics, mining, mechanics and drawing will be offered. There will be no fee for instruction. Small laboratory fees will be required. The course will aid candidates for positions under state civil service.

Some Interesting Oil Tests

Even to-day, one frequently hears engineers speak of oil "wearing out," some even going so far as to maintain that after oil has been in use for a certain length of time it should be discarded and replaced by new oil.

In order to determine exactly what deterioration oil suffered when in constant use, the Richardson-Phenix Company recently had a rather elaborate series of tests made on different samples of oil at the laboratories of Cornell University.

These tests proved conclusively that if oil is properly filtered it can be used over and over again indefinitely without losing any of its lubricating qualities. To show the value of the information obtained in these investigations, the data secured from the Hotel McAlpin tests has been selected as representing the most severe operating conditions.

The power plant of the Hotel McAlpin, New York City, is equipped with a Richardson central oiling and filtering system, supplying flooded lubrication to four Wetherill engines having forty-eight points of lubrication, two Clayton air compressors having six points of lubrication, two Laidlaw-Dunn-Gordon compressors having sixteen points of lubrication and one Wetherill crank-and-flywheel pump having thirty-two points of lubrication, making a grand total of 134 points of lubrication supplied by the system.

This plant operates twenty-hours per day, 365 days per year, and the average temperature in the engine room is 100 deg. Fahr. On account of the great variety of machines lubricated, the high load factor and the exceptional temperature conditions, the work imposed on this lubricating system is probably as severe as can be found in any power plant. The oil is a good grade of mineral oil, known as "extra brand engine oil."

To find out exactly how much oil was circulated through the oiling system, ten tests were made at the power plant and it was found that the *average* amount of oil handled by the lubricating system was 150 gal. per hour, or 3600 gal. of oil per day. This is an equivalent of 1800 bbl. per month. It is interesting to note that although this enormous amount of oil is supplied continuously to the bearings, it is only necessary for this plant to add to the system 3 bbl. of oil per month, but even these 3 bbl. cannot be charged to natural shrinkage in the system, for large quantities of oil are drawn off from the filters and used in cans for hand-oiling of small pumps, valve gears and other bearings not connected to the oiling system. But even charging 3 bbl. against the system it is evident that this plant pays for less than two-tenths of 1 per cent of the oil used for lubrication.

To determine the changes undergone by the oil, a sample of the new oil as received in barrels from the manufacturers was secured and also a sample of the oil drawn off from the clean-oil compartment of the filter. These samples were sealed in the engine room and shipped to the testing department at Cornell University, where without any further purification or filtration, a series of tests were made under the supervision of Professors Carpenter and Sawdon. The results of these tests are given in the accompanying tables and curves. They prove that a modern oiling system is without doubt one of the best investments that can be made in any power plant.

A series of friction tests were made on a Thurston railroad lubricant tester, having a hardened steel journal and bronze bearings with a total area of 20 sq. in. In all tests the testing machine was run at a constant speed of about 360 r.p.m. and the load applied in increments of 1500 lb. total pressure of 75 lb. per square inch. The test at each load was continued until the

friction and temperature of the bearings had become constant. The oil was fed upon the side of the bearing through a sight-feed oiler and the feed maintained as nearly constant as possible throughout all the tests. Readings were made at ten-minute intervals and a large amount of interesting data secured. The summary of these tests is shown in the following tables:

SAMPLE "A"—NEW OIL

	Press. on bearing, total lbs.	1500	3000	4500	6000	7500	
Press. on bearing, lbs. sq. in.	75	150	225	300	375		
Duration of test, mins.	120	50	60	60	50		
Temperature of bearing, max.	114.5	120.0	129.5	139.0	143.5		
Temperature of room, aver.	68.2	70.7	71.5	72.5	73.0		
Diff. in temp. bearing and room	46.3	49.3	58.0	66.5	70.5		
Rate of feed, drops per min. aver.	34.8	38.4	33.6	37.0	38.2		
Speed, R.P.M.	362	361	361	361	359		
Speed, ft. per min.	355	354	354	354	352		
Minimum coeff. of friction	.01166	.00666	.00533	.00458	.00373		

SAMPLE "B"—PURIFIED OIL FROM RICHARDSON FILTER

	Press. on bearing, total lbs.	1500	3000	4500	6000	7500	
Press. on bearing, lbs. per sq. in.	75	150	225	300	375		
Duration of test, mins.	150	60	60	80	50		
Temperature of bearing, max.	120.0	125.5	132.5	144.5	147.2		
Temperature of room, aver.	74.0	74.8	75.3	77.0	77.5		
Diff. in temp. bearing and room	46.0	50.7	57.2	67.5	69.7		
Rate of feed, drops per min. aver.	38.9	40.3	37.4	40.5	41.4		
Speed, R.P.M.	363	363	360	361	358		
Speed, ft. per min.	356	356	353	354	351		
Minimum coeff. of friction	.01265	.00717	.00522	.00458	.00367		

The coefficient of friction in the above table represents the lowest value found for each load, that is, as

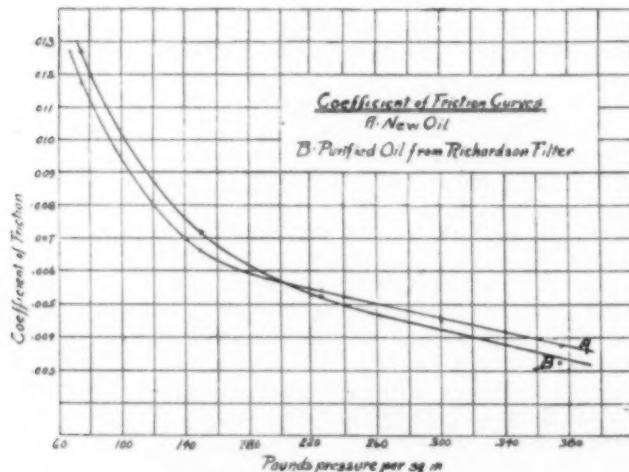


FIG. 1—COEFFICIENT OF FRICTION CURVES

soon as a given load is applied, the coefficient is, of course, high at first, gradually falling off until it becomes practically constant. This latter figure is the one shown in the table and represents the value that would obtain in ordinary practice where engines operate continuously for more than an hour. The temperature readings given in the table are the highest temperature reached for each load, that is, as each new load is applied, the bearing gradually heats up until the temperature becomes practically constant.

The difference in temperature between the bearing and the room have been plotted in the curves shown in Fig. 2. Curves showing the coefficient of friction of the new and filtered oil are shown in Fig. 1.

As mentioned above, 3 bbl. of new oil are added to this system per month. However, the system as a whole has been in operation for over a year and a half and the question naturally arises, what physical changes, if any, has the oil undergone during this extended period?

The results of tests made to determine this are given in the following tables:

PHYSICAL PROPERTIES
Sample "A"—New Oil

Color:	medium red, translucent	3.48
Flash point:	410° F. (open cup)	3.46
Burning point:	460° F. (open cup)	3.45
Specific gravity at 60° F. water as 1 = .895		2.14
Viscosity (with Olsen viscosimeter)		1.63
Water as 1 at 60° F. time 27.9 sec. for 100 cc.		1.57
Temperature F.	Time 100cc. secs.	Relative Viscosity
70	97.0	3.48
70	96.6	3.46
71	96.2	3.45
97	59.8	2.14
94	61.8	2.21
130	45.6	1.63
132	43.8	1.57
214	34.0	1.22
215	34.2	1.225

Sample "B"—Purified Oil from Richardson Filter

Color:	very dark red, opaque	4.94
Flash point:	410° F. (open cup)	4.80
Burning point:	440° F. (open cup)	4.66
Specific gravity at 60° F. water as 1 = .903		2.16
Viscosity (with Olsen viscosimeter)		1.81
Water as 1 at 60° F. time 27.9 secs. for 100 cc.		1.62
Temperature F.	Time for 100 cc. secs.	Relative Viscosity
68.0	138.0	4.94
69.0	134.0	4.80
70.0	130.2	4.66
103.0	60.4	2.16
114.0	50.6	1.81
130.0	45.2	1.62
152.0	39.0	1.40
147.5	40.2	1.44
218.0	33.2	1.19

The viscosity readings have been plotted in the form of a curve, shown in Fig. 3.

From the table it is evident that the oil has gained in specific gravity through constant use. This is what one would naturally expect inasmuch as the oil, in passing

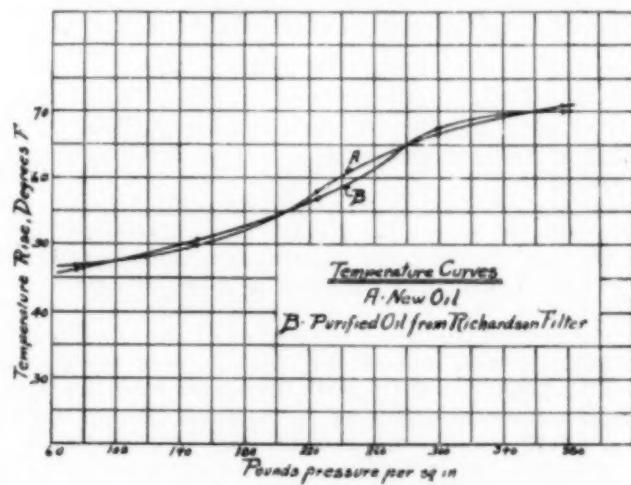


FIG. 2—TEMPERATURE CURVES

through the bearings has had some of its more volatile constituents driven off, also a small quantity of cylinder oil used for lubricating the piston rods and stuffing boxes naturally finds its way into the oiling system. The viscosity curves also confirm this hypothesis as the tests show that the used oil has a higher viscosity than the new, clearly demonstrating that as oil is used over and over again in an oiling system it actually gains in body, provided, of course, the filter thoroughly removes entrained water, and this is the vital point of the whole system.

The results of the friction tests as shown in Fig. 1 are also consistent with these physical changes. It will be noted that the new oil has a slightly lower coefficient of friction on low bearing pressures, while the purified oil shows a lower coefficient on higher bearing pressures. This is due to the fact just noted. In other words, the old oil, having more body, is better able to maintain a lubricating film when subjected to higher pressures. Of course, the difference between these two

curves is so slight that without any fear of contradiction one can say that for all practical purposes, properly filtered oil is as good a lubricant as new oil under all operating conditions.

The curves shown in Fig. 2 are probably the ones that will be most interesting to the operating engineer, as it is usually by the temperature of the bearings that he determines the quality of lubrication. As will be noted, these curves are practically superimposed and in no case is the variation more than a few degrees so that here again it is proven that filtered oil is as good as new oil.

Of course, it is needless to remark that in order to secure such remarkable results a highly efficient filter is necessary and the proposition of thus purifying oil on a commercial basis is naturally of considerable engineering interest. This plant is equipped with two new type Richardson power plant oil filters operating in parallel, each handling an average load of 75 gal. of oil per hour. In the design of these filters special attention has been given to providing a scientific method of precipitation.

Referring to Fig. 3, it will be seen that if the oil is heated to a temperature of about 150 deg. its viscosity is only slightly higher than that of water even after the oil has been in service a long time. Now, if oil at this temperature could be spread out in a very thin film, entrained water and other impurities which

ing a total filtering area of $3\frac{1}{2}$ sq. ft. On this basis the filters are handling in a most efficient manner 2.4 gal. of oil per square foot of filtering surface per hour.

As the tests prove that the oil is purified in a remarkable manner, it is thus seen that with a properly designed system of precipitation a large amount of cloth filtering surface is entirely uncalled for. The disposition of the filtering medium is of far more importance than its quantity. It would be just as logical to buy engines by the pound as to purchase an oil filter by amount of filtering surface it is supposed to have and disregard its efficiency. The arrangement of the filtering medium in the Richardson filter is such that it is free from wrinkles and folds. Every square inch of surface is effective and an equal thickness of the filtering medium is interposed in the oil circuit at every point.

Tests have proved that when filtering cloth is adjusted in any manner that constrains it to arrange itself in folds or plaits, the portions of the filtering surface where the folds come interpose a greater thickness and the oil does not pass through these parts but is short-circuited through the single thickness portions, thus rendering large portions of the surface inactive. So efficient has its system of precipitation and filtering proven that the Richardson-Phenix Company has now successfully applied this principle to its entire line of filters, ranging from small hand filters having a capacity of a few quarts per hour to large filters capable of handling over 7500 gal. an hour.

The fact that a power plant like that in the Hotel McAlpin pays for less than two-tenths of 1 per cent of the amount of oil used and that oil can be purified in a commercial filter and returned to an oiling system in a state of purity equal to new oil, is certainly of vast importance in the economical operation of power plants, and the old-fashioned idea of purchasing a barrel of oil and letting it drip to waste is certainly as out of date and uneconomical as Watts' original scheme of condensing the steam directly in the engine cylinder. The saving in the cost of the oil in the above plant by the use of the oiling system amounts to over \$2,000 per month, but who can compute the amount of coal saved by the reduction of friction or how much wear and tear on the machinery is reduced. It is safe to say that the money value of these savings is at least as great as the reduction in the oil bill.

The above data was furnished by the engineering department of the Richardson-Phenix Company, lubrication engineers and manufacturers, Milwaukee, Wis.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in December, 1913, was 60. The quantity of ore milled during that period was 2,014,358 tons. There were 9722 stamps in operation, with an average duty of 8.63 tons per 24 hours. Tube mills in commission numbered 287. The yield for the month was 672,815 fine ounces gold. This report shows a marked decrease in tonnage treated and gold recovered as compared with the same month in 1912.

The International Engineering Congress is making rapid progress in working out the final program of papers to be presented at the sessions in San Francisco in 1915. The first volume of publications will consist of a series of articles descriptive of the technical features of the design and construction of the Panama canal. Each of the topics will be treated by some one of the canal force who has been responsible for the design and construction described. The program for the other sections of the congress is practically complete, and notices will be published in the near future. Membership in the Congress on March 1 was over 1200.

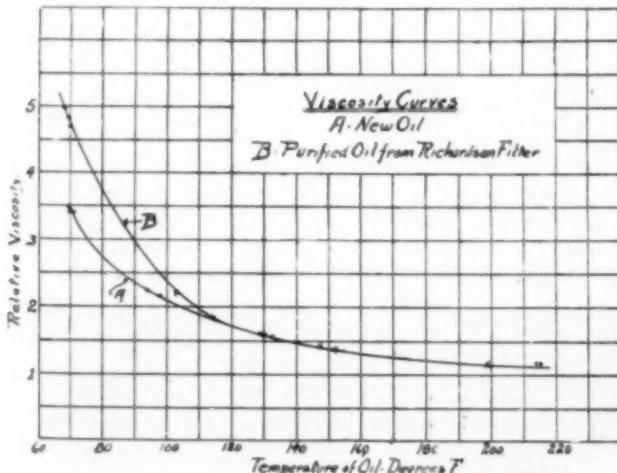


FIG. 3—VISCOSITY CURVES

are heavier than oil would settle out very rapidly. Of course, it is impossible to spread the oil out very thin in a commercial filter handling large quantities of oil, as the size of the filter would be prohibitive. However, this principle has been utilized in the new Richardson filter. The dirty oil is first heated as it passes into the filter, after which it is carried to the bottom of a precipitation compartment where, by a novel arrangement, the oil is spread out to an area of about 14 sq. ft., but this compartment only occupies $2\frac{1}{2}$ sq. ft. of floor space. The velocity of the oil in passing through this precipitation process is reduced to 0.2067 ft. per second. This extremely low velocity allows plenty of time for the precipitation process to be carried out in a highly efficient manner. The importance of thoroughly separating entrained water from the oil is demonstrated by the fact that at the Hotel McAlpin about 4 gal. of water per day is automatically separated and ejected from the precipitation chambers of the filters.

The oil after being separated from entrained water and heavy particles of foreign matter in the precipitation chamber then passes directly to the filtering chambers, each of which contains twelve filtering units hav-

A New Continuous and Dustless Dryer for Sludge Material

Drying is often a most trying proposition for chemical and metallurgical engineers, especially if the material to be dried is in a sludgy form and of such a chemical nature that the production of dust would seriously affect the welfare of the workmen.

What appears to be a very interesting and promising advance in the right direction is the recent development of the Macklind annular dryer by the Sherwin-Williams Company, of Cleveland, O., and its first instal-

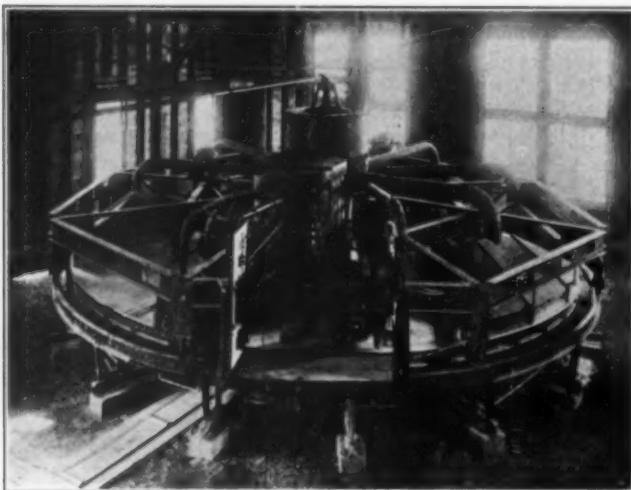


FIG. 1—MACKLIND ANNULAR DRYER AT OZARK SMELTING & MINING CO.

lation at the Ozark Smelting and Mining Company's plant at Coffeyville, Kan.

This machine was invented by Mr. W. R. Macklind, Managing Engineer of the Sherwin-Williams Co., and the specific purpose of the design was to produce a dryer that was continuous in operation, dustless and of high efficiency.

The principle of the Macklind dryer is to form a thin film, dry it and remove it in the shortest possible period in order that the material dried cannot be affected by the temperature. For this purpose the dryer is built in annular form and the period during which each film is being fed to the dryer, dried and removed is one revolution of the dryer.

The manner of operating at Coffeyville is as follows: The sludge material to be dried is pumped to the machine, varying from 60 per cent water and 40 per cent solids to 50 per cent water and 50 per cent solids. This sludge is delivered to the feeding cylinder over the feeding device, which device in turn deposits it on the annular surface of the machine. The spider of the machine revolves. The annular drying surface is stationary. The revolving medium makes a revolution every three to one and one-half minutes.

The machine being started, the feeding device thereupon commences to feed the sludge material in a thin film on the drying surface. In turn when the machine has made one revolution from the initial starting point, the removing device commences to operate, removing the dried material and carrying it to the center of the machine for final delivery to the packers.

From this time on the operation is continuous, feeding and removing, and the operator's only duty is to watch the machine and see that it is properly oiled and the proper speed of rotation is kept. This, however, becomes constant after the machine is set.

All vapor arising from the dried material is removed

by means of the vapor hoods and connection pipes through the central vapor drum into the atmosphere. The circulation of this vapor-removing medium is carried on through induced draft.

All dust arising from the removing device is collected and deposited in a small bag collecting device in the center of the machine.

The Macklind dryer has been operating for some sixty days at Coffeyville on lead pigment and in addition extensive tests have been made in drying pulp white lead. These tests were carried on in the presence of experts from the National, Eagle White Lead and Hammar Brothers White Lead Works, and are stated to have proven conclusively the efficiency of the machine in drying white lead pulp from the standpoint of efficiency, continuity, rapidity and dustlessness. This latter feature is one of the most important phases of this new machine. The success of the machine in drying sludge white lead dustlessly—which is recognized to be one of the most difficult propositions—appears to open to the Macklind dryer a wide field of usefulness. For this reason the following details of its construction should be of general interest.

The dryer is circular and weighs 80,000 lbs. erected. It is 30 ft. in diameter and requires 14 ft. head room. The surface of the drying table is 40 ins. above the floor. The drying table, which is 6 ft. wide, consists of 40 semi-steel sectors and has a drying surface of 414 sq. ft. The sectors of the drying table are tested to 150 lbs. hydrostatic pressure.

The drying table operates with a pressure of steam from 50 to 90 lbs. The temperature of the drying table at 90 lbs. pressure is 330 deg. F., which is the maximum temperature at which the machine operates. The dryer is operated by three direct-current electric motors of 5 hp, 3 hp and $\frac{3}{4}$ hp respectively.

The material to be dried is forced by a rotary pump to brass reservoirs over feeding device. This reservoir serves the brass vibratory feeder which places the sludge on the drying table. The pressure of the ma-

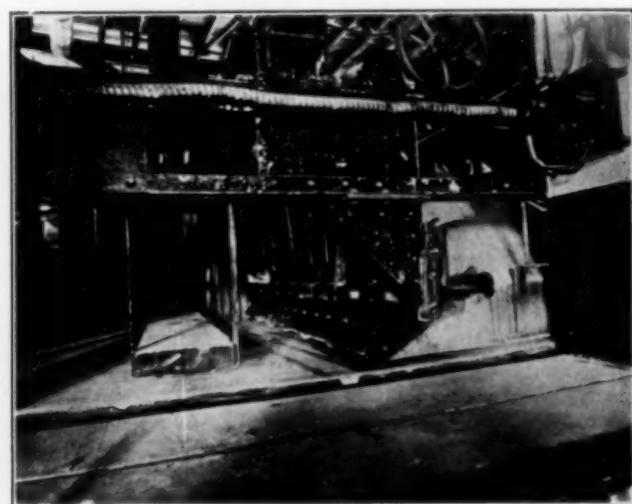


FIG. 2—FEEDING MECHANISM OF DRYER

terial being fed is held constant by means of static head maintained by a rotrex pump. The dried material is removed by means of an enclosed removing device.

As described before, the material is dried in one complete revolution. This takes from one to three minutes. White lead and leaded zinc pigments dry thoroughly with no perceptible moisture in one to one and one-half minutes.

The operator can control the rotating speed of the machines at will, so that one revolution may take from

one minute to three minutes, or any intervening period.

While the machine will handle sludge materials containing 40 per cent water and 60 per cent solids or 50 per cent and 50 per cent respectively, it will not operate successfully if the sludge does not carry at least 40 per cent of water.

The dried material can be packed direct from machine without pulverizing, if desired, as it is in a granular state.

All vapors arising from the drying process are imme-

75 per cent, though it naturally varies, depending on conditions. With dry steam and 50 to 45 per cent sludge a 75 per cent efficiency can be maintained. From the results obtained at Coffeyville it appears that the cost of drying sludge material as compared with dry-pan practice is cut in two.

In calculating the efficiency of the dryer, the formula $E = 100 a/b$ is used, where E is the efficiency of the machine, a the heat utilized in evaporating water in the sludge to be dried and b the total heat supplied to the annular table.

While the efficiency was stated before to average 75 per cent, the actual figures obtained with the machine in drying sludge consisting of 55 per cent water and 45 per cent solids were as follows: 2444 lbs. of water were to be evaporated for every 2000 lbs. of dried material. The number of B.t.u. required to evaporate the 2444 lbs. of water was 2,800,824, while the B.t.u. deliv-

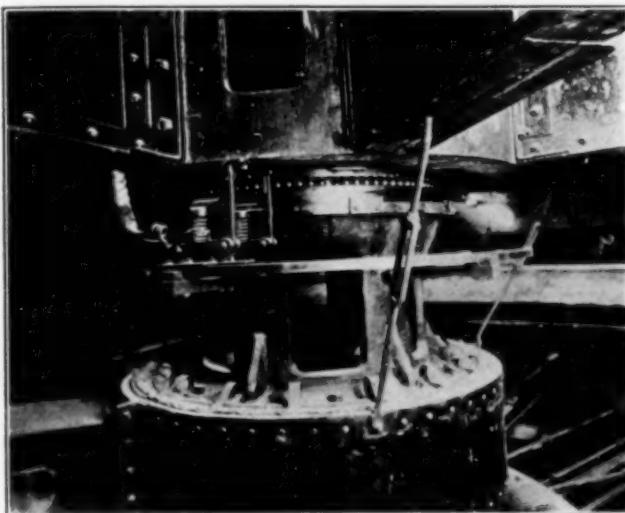


FIG. 3—CENTRAL COLUMN OF DRYER

diately removed and discharged into the air. The condensation from the drying table handled by trap can be used as pure water for manufacturing or returned to the boilers if desired.

The machine is operated by one man who has full control of all its movements which are handled from the operating platform which revolves with the ma-

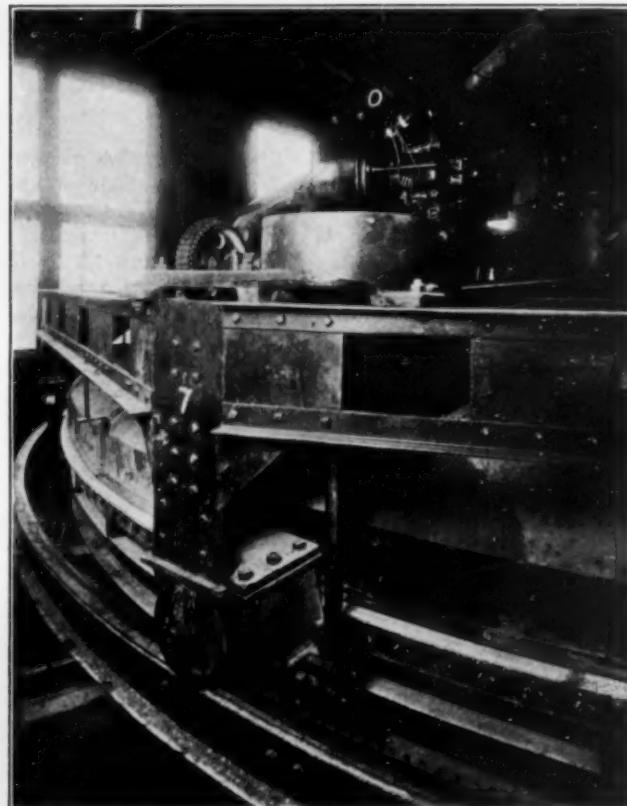


FIG. 4—DETAILS OF DRYER CONSTRUCTION

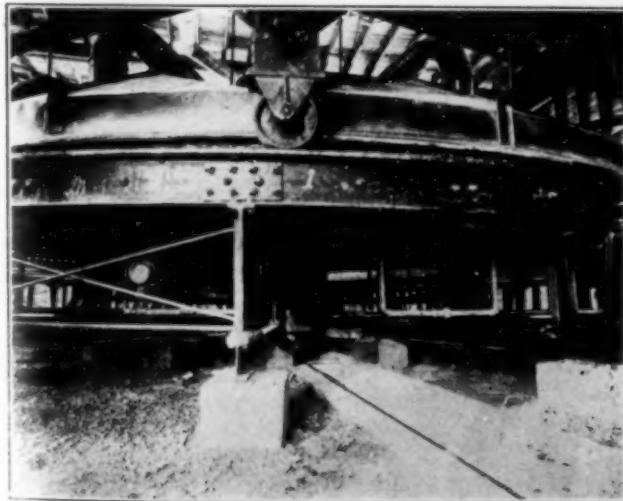


FIG. 5—DETAILS OF DRYER CONSTRUCTION

chine. All movements are operated by electric motors. A dust collector takes care of the dust made in the removing device.

The use of steam in the machine insures an even temperature throughout the annular dryer table. The use of steam makes it possible to regulate the temperature according to the character of material being treated.

The efficiency of this dryer is stated to average about

ered to the annular dryer in the steam was 3,552,000. Therefore, according to the above formula, an efficiency of 78.8 per cent was obtained.

Fig. 1 shows the Macklind annular dryer as installed in Coffeyville, Kans. While its minimum capacity is 2000 lbs. of dry material per hour (the material going on machine from 55 per cent water and 45 per cent solids), the machine has a record of 3361 lbs. dried material per hour. This rate was maintained for a run of nine hours continuously.

Fig. 2 shows the bronze feeding mechanism of the dryer. This mechanism makes 300 vibrations per minute and sludge material is thereby fed in a perfect film onto the drying surface of the machine, shown directly underneath the feeding device.

Fig. 3 shows the central column of the dryer with the following details: Ball bearings of revolving frame spider, direct-current trolleys for supplying current for operating machine, revolving dust-tight drum connecting with jumper conveyor, which transmits dried ma-

terial from table to center of machine for discharge.

In Fig. 4 are shown the main motor drive for rotating machine frame, radial rack of machine, details of castor at pinion drive, vapor hoods as suspended above drying table, ends of cast iron sectors showing core drawing plugs, vapor collecting drum in center of machine with main vapor discharge stack and induction air jet.

The details shown in Fig. 5 are steam connections, draining connections to sectors, super-structure frame, foundations, gauges for indicating pressure on sectors, vapor collecting hoods and supporting castor for revolving spider.

As the problem of drying materials in a sludge form comes up so often in chemical and metallurgical practice it will be interesting to watch the further career of the Macklind dryer after it has shown its usefulness for white lead. It is now being put on the market by the Sherwin-Williams Company, 601 Canal Road, Cleveland, Ohio.

Duriron Castings for Chemical and Metallurgical Purposes

Among recent iron alloys, invented for special purposes, "duriron" is of particular interest to chemical and metallurgical engineers on account of its remarkable resistivity to chemical action.

Duriron is an iron alloy containing from 12 to 15 per cent silicon, while its other ingredients are being kept secret. It is suitable for most chemical apparatus



FIG. 1—DURIOR EJECTOR

or machines that can be cast and finished by grinding. Duriron is too hard to be machined.

The specific gravity of duriron is 7; that is, it is 4 to 7 per cent lighter than cast iron. The weight per cubic inch is 0.252 lb.

The tensile strength of duriron is 12,000 lb.; the compression strength 70,000 lb. The melting point is 2550 deg. Fahr. Its heat conductivity is higher than that of cast iron. It takes and retains a polish like nickel. In the design of duriron apparatus its shrinkage and high coefficient of expansion must always be considered. The shrinkage is 3/16 inch to the foot, the coefficient of expansion 0.00001565 per degree Fahr.

The most remarkable property of duriron is, as stated, its resistivity to corrosion. With few exceptions, duriron is not attacked by acids or alkalies of any strength. Of course, the resistivity of duriron to chemical attack depends somewhat on the temperature, decreasing slightly with higher temperatures.

The following results of immersion tests show the action of various acids on duriron.

Immersed in cold 25 per cent sulphuric acid, duriron showed no loss in one year, while cast iron was completely dissolved in sixteen days and wrought iron in thirty days.

Immersed in cold 25 per cent nitric acid, duriron showed a loss of 0.015 per cent in one year, while cast iron was completely dissolved in sixty-three hours and wrought iron in fifty-eight hours.

From results in actual practice it may further be stated that duriron is unaffected by acetic, tannic, hydrofluosilicic acid, copper sulphate, etc. It is resistant to phosphoric acid up to a certain strength, and is sometimes attacked by sulphurous acid. Duriron connecting-pipes of nitric and sulphuric acid stills have shown no apparent corrosion after one year of service.

The experience of a large aniline-color manufacturing plant is particularly suggestive. They have determined that in dyeing wool and cotton exactly the same shade and color may be obtained in duriron vessels as in porcelain. The slightest trace of dissolved iron would have a marked effect on the resultant color.

As to the resistivity of duriron to mechanical erosion as distinguished from chemical corrosion the report on the behavior of a duriron scraper in a salt cake furnace is interesting. In twenty-eight days of continuous operation at 900 deg. Fahr. the duriron scraper wore down $\frac{1}{2}$ in., while cast-iron scrapers under the same conditions of operation wore down 3 inches. On account of this remarkable resistivity to erosion duriron is now being considered in connection with pneumatic ash-conveyor systems.

The adjoining illustrations show some interesting castings for chemical and general industrial work built by the Duriron Castings Company, 90 West Street, New York City, in their foundry in Dayton, Ohio.

Fig. 1 shows a steam syphon of duriron. One has been in use since last September with strong sulphate of alumina and so far not the slightest trace of corrosion or erosion has been found.

Fig. 2 shows a duriron centrifugal pump. In this

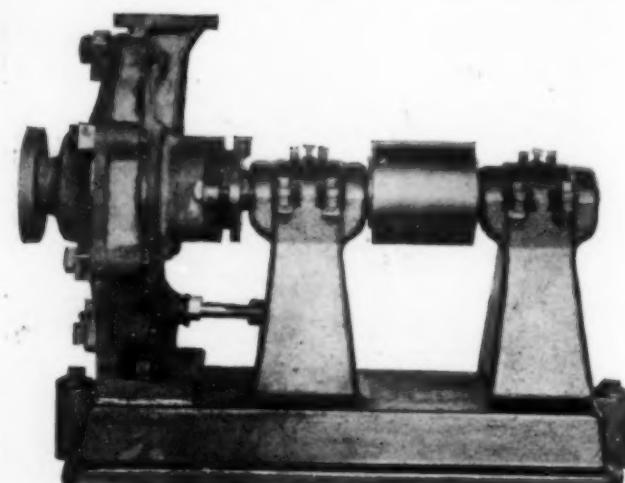


FIG. 2—DURIOR CENTRIFUGAL PUMP

case both the resistivity of the duriron to chemical attack by acids and its resistivity to erosion by grit and hard material are proving to be of greatest advantage. These pumps are of a very refined design and embody various features of particular value in pumps for handling acids.

Fig. 3 shows a partial installation of standard duriron pipe and a regular duriron cock, slightly modified

to meet conditions. This standard pipe can be cut to length on order, and the use of compression couplings not only insures a stronger line, but each coupling constitutes an expansion joint. The Duriron Castings Co. also manufacture all kinds of special pipe. This pipe is used not only in chemical and metallurgical works, but is now also being widely employed in municipal water systems as they are not affected in the least by

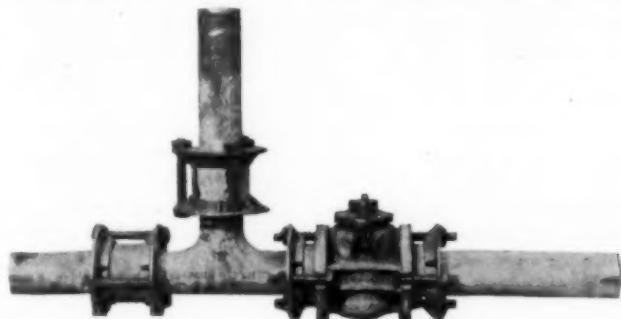


FIG. 3—DURIORON STANDARD PIPE INSTALLATION

the sulphate of alumina solution employed in rapid filtration systems or by hypochlorite solutions now so generally employed as an after-treatment in water purification.

Duriron cocks have recently undergone a careful redesign and reconstruction in which among other things special attention has been paid to correct taper which in general is hardly given the attention it deserves. As an illustration of their durability it may be stated that after months of continuous service, handling mixed acid (nitric as low as 18 per cent.) at 80 lbs. pressure, no corrosion or erosion could be detected. One of the great practical advantages of duriron cocks is that they do not stick even after long periods of idleness. Some users never grease them, some grease every four or five months, and others every four or five weeks. Their cost of maintenance is, therefore, very slight.

A Small-Size Electric Arc Furnace for Melting and Refining

In 1912, Mr. Ivar Rennerfelt, a Swedish engineer, constructed at Hallstahammar, Sweden, an electric furnace, embodying some interesting novel features. The

trial was so successful that, within a year, a steel foundry containing four Rennerfelt furnaces was erected at Hallstahammar.

Since then eleven other Rennerfelt furnaces have been erected or are in course of construction in various other plants in Sweden, Norway and Russia.

The principal field of the furnace is that of an economical small furnace for crucible works, steel foundries, copper and alloy foundries, etc. Its principle is applicable to small units of 100 kg as well as larger sizes, and the capacity can be multiplied almost at will

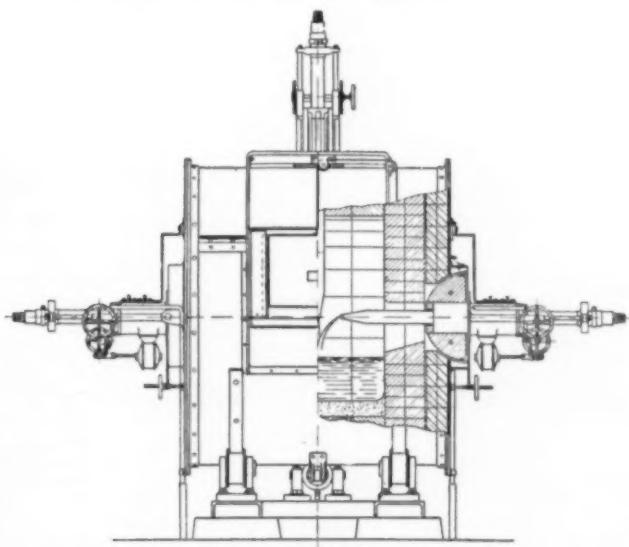
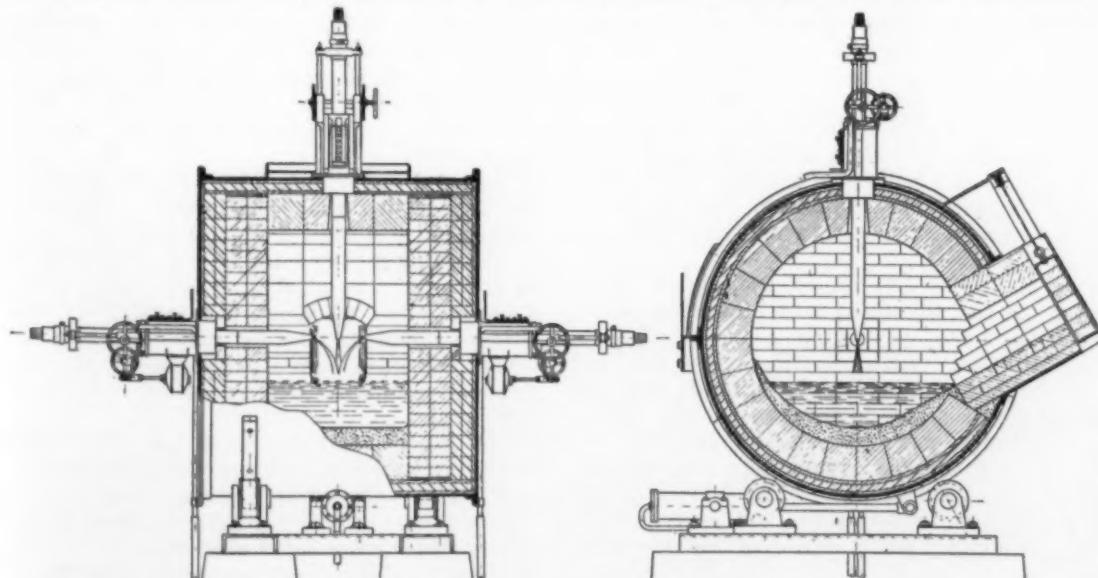


FIG. 3.—MODIFIED DESIGN

by putting together a number of units as will be described later.

The Rennerfelt furnace is essentially a two-phase furnace. In case the plant is supplied with three-phase currents the well-known Scott transformation is employed to change the three-phase to two-phase currents.

There are three electrodes; one central electrode descending vertically through the crown of the roof, flanked on both sides by horizontal electrodes entering through the sides of the furnace. Fig. 1 shows the arrangement of electrodes with the side-electrodes sliding in fixed holders, but adjustable axially by hand or motor power. Fig. 2 represents a section of the same fur-



FIGS. 1 AND 2.—TWO VERTICAL SECTIONS OF RENNERFELT FURNACE

nace showing the charging and casting door placed in the circular wall.

Fig. 3 shows a sectional view of a furnace with the horizontal electrodes adjustable in the vertical plane. Electrodes adjustable vertically are preferably used when the furnace is employed for melting light scrap, requiring much space below the arcs, before it is melted.

The two side electrodes are connected to the two phases of the two-phase system respectively, while the vertical top electrode is connected to the neutral point.

Fig. 4 shows clearly the electrical connections.

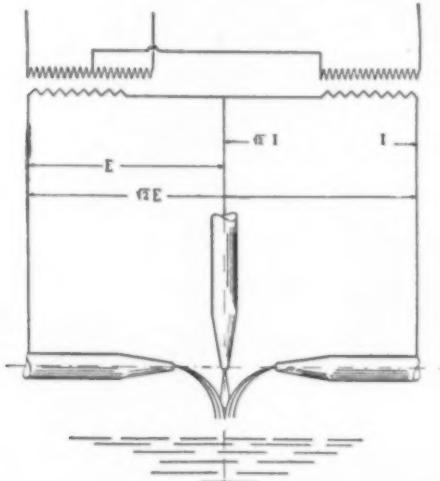


FIG. 4—ELECTRIC CONNECTIONS OF ELECTRODES

The principal novel feature of the Rennerfelt furnace is that as a result of the magnetic fields produced by the currents in the electrodes and in the arcs themselves, the arcs are deflected downwards onto the bath, thus forming the arcs into an inverted arrowhead or *fleud-de-lys*. The heat generated in the arcs is thus concentrated down upon the bath, though the electrodes do not touch or even approach the slag or metal. The arcs are sweeping or brushing all over the central space underneath the points of the electrodes, insuring a uniform heating of the charge and rendering the slag very fluid and chemically active. The height of the arcs from the points of the electrodes to the surface of the bath can be adjusted, but is usually kept at about 6 to 12 in.

In the riveted and strongly braced steel shell of the furnace is placed an insulating lining of asbestos board. Silica or first-quality firebricks in rings are built up against the asbestos board and form the bedding for the actual inner lining, acid or basic. This is made of special bricks requiring no cutting and set in rings of different diameters so as to form an egg-shaped interior melting chamber. The bull's eye around the charging door is carefully fitted into the lining. Special bricks form circular openings through which the electrodes enter into the furnace.

The life of the lining has not yet been finally established during the few months of actual operation, but a furnace with basic roof and hearth has run 102 heats without requiring any repairs outside of the ordinary fettling. A furnace with acid roof and lining operated continually day and night during two months and a half on acid tool steel, running not less than 174 heats. The temperature in the basic was kept considerably higher than in the acid furnace. The bottom of the hearth is practically undestroyable and may be used over again continuously when repairing the side walls and the roof.

The radiating heat from the free-burning arcs is reflected on to the bath from the entire mirror-like in-

candescent inner surface of the vault. Yet the arcs are at such a distance from this roof that the danger of melting the same is minimized. The shadow of the vertical electrode has a marked protecting influence on the vulnerable portion of the vault—the area around the entrance opening for the said electrode.

There is no sudden break between the roof, sidewalls and bottom, all being built together in one continuous curve. Owing to the circular form of the roof, the arch is very strong, and the disadvantage of expansion and contraction of the lining is greatly reduced.

As to the consumption of the electrodes the following information is given:

In a 600-kg. (1320-lb.) furnace running continually on charges of cold scrap and pig the average consumption of electrodes has been found to be about 2.8 kg. (6.2 lb.) per ton of steel. This figure represents the gross consumption, as there are no stumps left unconsumed.

Even when melting pig iron and afterward decarbonizing it by means of ore, the consumption of electrodes has not exceeded 3 kg. (6.6 lb.) per ton, in spite of the highly oxidized slag carried on the charge.

The wear of the side electrodes in a small furnace with acid lining using side electrodes of 2-inch diameter amounts to about 1 inch of electrode per hour.

Three such electrodes being used, wear of the electrodes in 24 hours will equal about 6 kg. (13.2 lb.). If the furnace is kept running at full power, 5 heats of 600 kg. (1320 lb.) or 3 tons of steel are produced in 24 hours, making the consumption of electrodes 2 kg. (4.4 lb.) per ton, if reasonable care is exercised.

The power factor is stated to be above 0.9. In one instance a value of 0.97 has been ascertained at a furnace operated with a current of 50 periods.

As to specific power consumption the following data are given:

According to records taken by registering kw-hour-meters a small furnace of 600 kg. (1320 lb.) at the Ljusne ironworks melted and refined a full charge of cold scrap with not more than 700 kw-hr. per ton. The normal rating of a furnace of this capacity is 125 kw, but according to records 80 to 90 kw are sufficient to complete a 600 kg. heat in 5 hours' time, indicating a very satisfactory thermal efficiency even when running with only 75 per cent. of full load. White pig iron has been melted in the same furnace under similar conditions with 405 kw-hr. per ton. This figure is an average of four consecutive records.

In one instance gray pig iron was melted and overheated with 425 kw-hr. per ton, including the melting of 22 kg. basic slag per ton of iron. Under very favorable conditions it has, however, been possible to melt gray pig iron with about 300 kw-hr. per ton in a 600-kg. furnace.

Repeated and successful trial runs have proven that the Rennerfelt furnace is also well suited for producing high-grade tool steel from pig and ore. As indicated by recording meters a ton of pig iron charged cold can be converted into steel in a fairly large furnace with a consumption of about 850 kw-hr. If the iron is charged liquid, 350 kw-hr. may be saved; 500 kw-hr. would, therefore, suffice to decompose the ore required and to deoxidize the steel resulting from 1 ton of liquid pig metal.

The furnace is being used for steel foundry work producing excellent castings, thin-walled and of intricate forms. The steel is tapped very hot and often requires to be held in the ladle for sometime until sufficiently cooled off to make good castings. Cracks due to shrinkage and blowholes seldom occur in steel foundries using this type of furnace. Nickel-steel castings, manganese steel and acid tool steel have all been success-

fully made in the furnace. Motor-cylinders and other high-class pieces in pig iron have also been cast with perfectly satisfactory results.

The Rennerfelt furnace has also been employed for copper and brass melting. A small furnace of about 60 kw was charged with 95 kg. copper after having

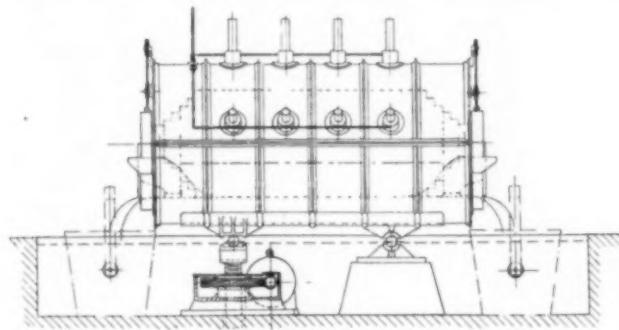


FIG. 5—MULTIPLE-UNIT FURNACE

been brought to full temperature. The charge was completely melted after 30 minutes with an expenditure of 30 kw-hr. or about 300 kw-hr. per ton. Another charge of 44.5 kg. copper and 30 kg. zinc was entirely melted after 20 minutes, the energy consumed being 20 kw-hr. or 268 kw-hr. per ton of brass. The metal was poured into ingot molds and afterward drawn into tubes of excellent quality. At another occasion, the furnace was used for melting about 350 kg. of copper scrap with satisfactory results, the charge melting in a few minutes. The copper was perfectly dead and was cast into small blocks.

The energy consumed per ton will, of course, be materially reduced, when dealing with larger charges in furnaces especially designed for special metals. The figures already obtained indicate, however, that the furnace will successfully compete with the crucible in brass foundries, especially as there is practically no loss from oxidation and as the metal is materially improved.

In order to make this furnace adaptable to large sizes, the "multiple-unit arc furnace" design is employed as shown in Fig. 5, which illustrates a furnace made up of four unit sizes side by side. The furnace is built as an elongated crucible of preferably cylindrically cross-section, made up of a number of similar sections bolted to one another and each fitted with one set of electrodes.

The patent rights of the Rennerfelt furnace are owned by the Aktiebolaget Elektriska, Ugnar, Fredsgatan 2, Stockholm, Sweden.

Personal

Mr. G. D. Van Arsdale, chemist for the Phelps-Dodge interests at Douglas, Ariz. stopped in Denver last month to visit the plant of the National Radium Institute, of which Dr. James Douglas is one of the organizers. Mr. Van Arsdale will return to Arizona in about a month, after a trip through the East.

Mr. Charles F. Burgess, who for a number of years has been in charge of the Chemical Engineering and Applied Electrochemical Departments of the University of Wisconsin, has resigned his professorship to devote himself to the management of the Northern Chemical Engineering Laboratories with offices at Madison, Wisconsin. These laboratories are carrying on experimental and development work in chemical, electrochemical, and metallurgical engineering. Included in its technical staff are Carl Hambuechen, E. E.; Otto E. Ruhoff, B. S.; Walter B. Schulte, Ch. E.; L. T. Richardson, Ch. E.; O. W. Storey, Ch. E., and Arden R. Johnson, Ph. D.

Mr. Charles Butters has returned to this country from a visit to Salvador where he inspected the Butters properties.

Mr. Franklin Guiterman, of the New York office of the American Smelting & Refining Co., has been making a trip of inspection among the Colorado smelting plants owned by the company.

Mr. J. M. Hyde has returned to this country after a trip through Europe investigating new metallurgical processes. He will be American representative for the Murex Magnetic Co., Ltd., with headquarters at San Francisco.

Mr. E. M. Johnson has resigned his position as manager for the National Zinc Co.

Mr. W. D. Leonard, superintendent of the Garfield smelter of the American Smelter Securities Co., made a brief visit in Denver last month.

Mr. L. M. Marshall has severed his connection with the Cambria Steel Company to become chief engineer and assistant general manager of Messrs. A. J. Haws & Sons, Ltd., refractory manufacturers of Johnstown, Pa.

Dr. Charles L. Parsons, chief of the division of mineral technology, U. S. Bureau of Mines, has been in Denver to inspect the newly completed plant of the National Radium Institute, which is to be operated under an agreement between the Bureau and the Institute.

Mr. August Raht, who was closely identified with the early development of smelting in Colorado, was in Denver last month on a visit from his home in Santa Cruz, Cal.

Mr. W. H. Staver, formerly superintendent for the Liberty Bell company in Colorado, is engaged in cyanide experiments at Sonora, Tuolumne county, Cal.

Mr. F. D. Weeks, of the American Metal Co., spent a part of March in Colorado, visiting the Denver offices and Salida smelting plant.

Digest of Electrochemical U. S. Patents.

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTROPLATING

3015, March 21, 1843, Daniel Davis, Jr., of Boston, Mass.

Relates to electroplating, particularly to electro-gilding, and produces a "dead-gilding" effect by first electroplating with copper, then a layer of gold, or of the metal required. The layer of copper produces a deadening of the final layer in a thorough and beautiful manner. With iron objects, cyanide of potassium is added to the copper sulphate solution sufficient to produce a solution of the copper in the cyanide of potassium. The iron is then coated with copper from this solution, after which a thicker coating may be applied from the sulphate solution. The gold is then deposited.

17,095, April 21, 1857, Alonzo G. Hull, of New York, N. Y.

Relates to electrolytic apparatus for medical use, and consists of two cells communicating through a submerged, porous diaphragm through which also is a valved opening. When the valve is opened, a graduated amount of circulation of the liquid takes place; when closed, the porous diaphragm allows electric action to take place.

26,978, January 31, 1860, Matthew Edwards, of Cambridge, Mass.

Relates to oxidizing metals for ornamental purposes, and consists in connecting the metal to be oxidized as an anode in a suitable electrolyte. With copper or brass, and an electrolyte of sodium chloride, a black coating is deposited, while with an electrolyte of potassium chlorate the metal will be colored red. If the surface contains silver or other white metal, weaker electrolytes are used.

27,046, February 7, 1860, William B. Gillett, of Auburn, N. Y.

Relates to sharpening files by electrolysis. The file is connected as an anode in an electrolyte of dilute sulphuric acid, or of a suitable salt, the cathode constituting a metallic plate, or the metallic lining of the tank. The file may also constitute the electropositive element of a voltaic cell.

82,525, September 29, 1868, Maurice Herrmann Jacobi and Eugene Klein, of St. Petersburg, Russia, assignors to Green, Clay & Company.

Relates to the electrodeposition of iron on molds for engraving, stereotypes, etc. The electrolyte consists of sulphate of iron combined with the sulphates of either ammonia, potash, or soda; or the chlorides of these metals may be used with the sulphate of iron. The bath should be kept as neutral as possible, but a small quantity of weak organic acid may be present to prevent precipitation of basic compounds of iron. A small quantity of gelatine improves the texture of the iron deposit. In order to increase the rate of solution of the iron anode, thereby maintaining the strength of the electrolyte, the anode may be short-circuited with a piece of gas carbon, or other electronegative element, the carbon being placed in the same electrolyte, or in a separate porous cell.

89,523, April 27, 1869, Hiram Tucker, of Newton, Mass.

Relates to ornamenting metal articles by electroplating, and consists in first enameling or varnishing the article, then grinding or otherwise removing portions of the coating, and electrodepositing the desired metal on the exposed parts.

90,894, June 1, 1869, Hiram Tucker, of Newton, Mass.

Relates to ornamenting metal articles by electroplating; it resembles the process described in patent No. 89,523, except that a final "show coating" of gold, etc., is deposited on the exposed metal.

97,390, November 30, 1869, Kingston Goddard, of Richmond, N. Y.

Relates to electroplating articles such as pitchers, etc., made of wood or other non-conducting material. The wood or other material is coated with plumbago, or other suitable conducting material, and electroplated with one or more coats of suitable metal.

97,657, December 7, 1869, Reuben Lighthall, of Brooklyn, N. Y.

(Reissued as No. 4048, June 28, 1870.)

Relates to preventing or retarding the oxidation of iron when in contact with water, especially salt water, and consists in the application to the iron of such electropositive metals as zinc, or alloys of zinc and tin, etc., or the two metals separately. The electropositive metal may be fastened under a bolt, or otherwise, to surface condensers, pipes, ships, etc.

100,038, February 22, 1870, James Spooner Howard, of Mansfield, assignor to himself; E. Adams, Jr., of Attleboro; T. E. Grover, of Mansfield, and N. Carpenter, of Attleboro, Mass.

Relates to electroplating antimony; the solution is made up of six fluid ounces of sulphate of ammonia, one-fourth fluid ounce of cyanide of potassium, eight fluid ounces of sulphate of antimony, and one gallon of (soft)

water. The solution is finally filtered. The proportions given may be varied to a small extent.

100,580, March 8, 1870, Elbridge G. Wright, of Boston, Mass.

Relates to ornamenting metals, etc., by electroplating, and consists in coating the article with a suitable resist, removing portions of the resist where it is desired to deposit, and cutting below the surface of the metal so that the deposit will be below the rest of the surface, thereby protecting it from being worn off when exposed, or while being cleaned, etc.

106,823, August 30, 1870, James Spooner Howard, of Mansfield, assignor to himself; T. E. Grover, of same place; E. Adams, Jr., and N. Carpenter, of Attleboro, Mass.

Relates to producing a permanent dull finish upon gun-barrels, etc., and consists in first nickel-plating the object, then electroplating iron upon the nickel; the iron is then oxidized with a solution consisting of $\frac{1}{2}$ oz. copperas, 2 oz. corrosive sublimate, 2 oz. blue vitriol, 3 oz. spirits of niter, $\frac{1}{8}$ oz. nitric acid, 2 qt. water. Several applications of this solution are applied to the iron deposit, an hour or more elapsing between successive applications, depending upon the color of finish desired.

109,508, November 22, 1870, Cornelius Godfrey and Reuben Lighthall, of New York, N. Y.

Relates to preventing iron from rusting, and consists in electrodepositing an electropositive metal, as zinc, or alloy, such as alloys of zinc and tin, on the iron to be protected.

113,090, March 28, 1871, John J. Pratt, of New York, N. Y.

Relates to the manufacture of sign plates, etc., and consists in painting letters and numbers with a suitable resist on a metal surface, electroplating the unpainted portions with a desired metal, and then removing the resist, exposing the letters and numbers in the underlying metal below the electroplated surface.

129,207, July 16, 1872, Leopold Brandeis, of Brooklyn, N. Y.

Relates to bronzing columns, pillars, monuments, etc., of iron, and consists in cleaning them with a sand blast, then applying a coating of copper from a solution of a copper salt, or by electrodeposition, then electrodepositing a coating of zinc or lead. If a bronze-antique is desired, a second deposit of copper is made on the zinc or lead coat.

149,974, April 21, 1874, George W. Beardslee, of Brooklyn, N. Y.

Relates to electrodepositing cobalt, and describes preparing an electrolyte by dissolving metallic cobalt in hydrochloric acid, evaporating the solution to dryness, dissolving from 4 to 6 oz. of the salt in a gallon of distilled water, and adding ammonia until the solution is slightly alkaline. The anode consists of cobalt granules or fragments surrounding a carbon plate, and enclosed in a porous sack or envelope. During electrolysis, care should be exercised that the electrolyte remains alkaline.

172,862, February 1, 1876, Isaac Adams, Jr., of Boston, Mass.

Relates to the electroplating of cobalt. Refers to the prior art as found in literature, and points out the disadvantages of several processes. Describes methods of preparing the double chloride of cobalt and ammonium, and of cobalt and magnesium; also the double sulphate of cobalt and ammonium, and of cobalt and magnesium. These salts are dissolved in water to a strength of 6° to 7° Baumé, and maintained neutral. Metallic cobalt is used for the anode, made by reducing tartrate of cobalt with lampblack in a hessian crucible. When electrodepositing on zinc, first give the zinc a coating of copper.